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CONTRACT NUMBER NAS8-21155
SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

CASE
FILE

Performed for

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

By

THE BENDIX CORPORATION
THE BENDIX SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

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BENDIX SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

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FOREWORD

SAFE OPERATING AREA (SOAR)

The Bendix SOAR principle is a method of specifying the Safe Operating Area for a transistor in a given application. SOAR defines the region which encloses all of the points representing simultaneous values of the collector current and the collector-to-emitter voltage which a transistor can safely handle under specified conditions of base current, time, junction temperature and average power dissipation. With transistors specified under the Bendix SOAR technique, second breakdown is virtually eliminated.

This report characterizes the Safe Operating Area of specific power transistors. The use of these Safe Operating Areas by designers will help avoid transistor second breakdown through design and quality considerations.

1.0 INTRODUCTION

The purpose of this contract was to determine the true dynamic characteristics, Safe Operating Area (SOAR), of selected power transistors used in critical space applications.

Testing to determine device parameters was made in accordance with JEDEC "Suggested Standard 65" and similar to MIL-STD-750A. Reference to the aforementioned documents is made, where applicable, in the specification section of this Final Report.

Copies of the JEDEC "Suggested Standard 65" are available from:

Electronic Industries Association
2001 Eye Street, N.W.
Washington, D.C. 20006

The MIL-STD-750A document may be obtained from:

Commanding Officer
Naval Publications & Forms Center
5801 Tabor Avenue
Philadelphia, Pennsylvania 19120

2.0 CONCLUSIONS

The specifications and SOAR curves generated as a result of this Contract verifies the actual power handling capability for each type of transistor. This information will serve to:

1. Provide valid derating information to establish necessary safety margins;
2. Provide guidelines for circuit analysis;
3. Provide documented Reliability Data;
4. Provide a means to improve the overall quality of devices now used by MSFC.

The individual reports contain a detailed analysis of Safe Operating Area for devices not previously characterized for SOAR. Highlights from each device are summarized here as a guide to design personnel.

- 2N1486 Manufacturer A. Suggest change of spec.
($\theta_{J-C} = 3^{\circ}\text{C/W}$) to extend DC power rating. 33W at $T_C = 100^{\circ}\text{C}$ provides safety margin for continuous operation. High energy device ideal for switching inductive loads.
- 2N1724 Manufacturer B. Device can sustain the rated power for all operating conditions.
- 2N1016D Manufacturer C. Device is capable of handling the manufacturers power rating.

- 2N1514 Manufacturer H. Marginal h_{FE} at 6A. Review circuits.
- 2N2102 Manufacturers D & J. Composite SOAR curves indicate that devices may vary from lot to lot by different manufacturers.
- 2N2034A Manufacturer E. Good energy dissipating capability.
- 2N2126 Manufacturer C. I_{CEO} should be part of specification to insure forward biased condition at high V_{CE} and low collector current.
- 2N657A Manufacturer E. A small device, heats up quickly causing failure at lower than published parameters.
- 2N697 Manufacturers G & E. Composite SOAR curves indicates a specification review of manufacturers E's device.
- 2N2880 Manufacturer H. Suggest continuous maximum DC rating be reduced from 5A to 3A. ($I_E = 5.5A$ discolors leads.)

The following devices have recently been registered by Bendix and are not specifically covered by this Contract, however the results and data are included without charge, as additional information for NASA personnel. The format used in the presentation of this data was recently developed for the registration of transistor specifications.

SOAR Characteristics:

	T_{STG}		T_J	V_{CEX}	V_{EBO}	V_{CBO}	I_C	P_T
	max	min						
2N5559	+200	-65°C	200°C	100V	7V	150V	10A	100W
2N5560	+200	-65°C	200°C	120V	8V	175V	30A	150W

The information obtained by this contract provides invaluable assistance to all concerned with the application, selection, performance, and most important, reliability of semiconductor devices in critical NASA systems.

The effect of SOAR evaluation is far-reaching, and should be a mandatory requirement for all power semiconductors being used by NASA in its Aeronautical and Space programs.

The Bendix Semiconductor Division hereby proposes that NASA continue this program with Bendix to further assist NASA in achieving the highest levels of Reliability in their programs.

Silicon Power Transistor
Type 2N1486

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer A --

Performed for
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GEORGE C. MARSHALL SPACE FLIGHT CENTER
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Contract No. NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline -- TO-8	
2.2.0	Terminal Designation	
	1 -- Emitter	
	2 -- Base	
	3 -- Collector	
	case -- Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.2</u>
	$T_{STG(min)} = -65^{\circ}C$	<u>JS-6-T1.1</u>
3.1.2	$T_J = 200^{\circ}C$	<u>JS-6-T2</u>
	$T_C = 100^{\circ}C, V_{CB} = 55V, P_T = 14.3W$	
3.2.0	Voltage	
3.2.1	$V_{CB0} = 100V$	<u>JS-6-T3</u> or MIL-STD-750, method 3001.1
3.2.2	$V_{EB0} = 12V$	<u>JS-6-T4</u> or MIL-STD-750A method 3026.1
3.2.3	$V_{CEX} = 100V$	<u>JS-6-T5-2.1</u>
	$I_C = 3.0A, V_{CC} = 100V, R_L = 33\Omega,$	
	$L = 1mH^*, CR -- 1N1204, V_{BB1} = 12V,$	
	$R_{BB1} = 10\Omega, V_{BB2} = 3V, R_{BB2} = 10\Omega$	
	Duty Cycle = 2%, $t_p = 1.65 ms.$	
	*Miller No. 7871 in series with Miller No. 7825-3	
3.3.0	Current	
3.3.1	$I_C = 3A$	<u>JS-6-T6</u> , $I_B = 300mA, T_C = 25^{\circ}C$

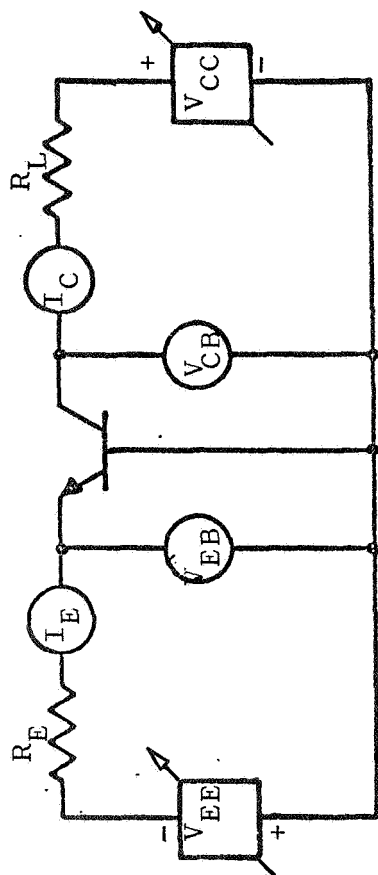
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.3.2	<u>JS-6-T8</u> $T_C = 25^{\circ}\text{C}$
3.3.3 $I_C = -3.5\text{A}$	<u>JS-6-T10</u> $I_B = 500\text{mA}, T_C = 25^{\circ}\text{C}$
3.4.0 Power	
3.4.1 $P_T = 14.3\text{W}$	<u>JS-6-T12</u> $T_C = 100^{\circ}\text{C}, V_{CB} = 55\text{V}, I_C = .26\text{A}$ Derating Factor - $.143 \text{ W}/^{\circ}\text{C}$
3.4.2 $P_{TM} = I_C V_{CC} = 150\text{W}$	<u>JS-6-T13</u> $T_C = 100^{\circ}\text{C}, V_{CC} = 50\text{V}, V_{BB} = 3\text{V}$ $R_{BB} = 10\Omega, I_C = 3\text{A}, \text{Pulse Width} = 5\text{ms},$ $\text{Duty Cycle} = 5\%, t_r \leq 50\mu\text{s},$ $t_f \leq 50\mu\text{s}$
3.5.0 Maximum Operating Condition	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> (See Figure 1) <u>Test Point</u> (See 3.4.1)
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T-14</u> (See Figure 2) <u>Test Points:</u> $T_C = 100^{\circ}\text{C}, V_{BB} = 3\text{V}, R_{BB} = 10\Omega,$ $t_r \leq 50\mu\text{s}, t_f \leq 50\mu\text{s}, I_C = 3\text{A},$ $\text{Duty Cycle} \leq 1\%, R_S = 0.1\Omega$ 1. For $t_p = 50\text{ms}: V_{CC} = 10\text{V}$ 2. For $t_p = 20\text{ms}: V_{CC} = 25\text{V}$

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.5.2 Pulsed Biased (Cont'd) Continuous DC SOAR	3. For $t_p = 10\text{ms}$, $V_{CC} = 40\text{V}$ 4. For $t_p = 5\text{ms}$, $V_{CC} = 50\text{V}$
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<u>JS-6-T5-2.1</u> with $L = 0$ and CR disconnected. See (Figure 3)
	<u>Test Points:</u> $R_{BB1} = 10\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 12\text{V}$, $V_{BB2} = 3\text{V}$, $T_C = 100^\circ\text{C}$, $t_f \leq 50\mu\text{s}$ (Coll. Current); $t_r \leq 50\mu\text{s}$ (Coll. Current), $R_S = 0.1\Omega$, $I_C = 3\text{A}$, $V_{CC} = 100\text{V}$
3.6.2 Clamped Inductive Load	<u>JS-6-T5.1</u> (See Figure 4) Test Points: (See 3.2.3)
3.6.3 Unclamped Inductive Load	<u>JS-6-T5.1</u> and CR disconnected (See Figure 5)
	<u>Test Points:</u> 1. $V_{BB1} = 12\text{V}$, $L = 20\text{mH}^*$ $R_{BB1} = 10\Omega$, $R_L = 4.1\Omega$ $V_{BB2} = 3\text{V}$, $V_{CC} = 12.5\text{V}$ $R_{BB2} = 10\Omega$, $f = 10\text{Hz}$ $R_S = 0.1\Omega$, $d = 15\%$ *Series Stancor C-2688

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
3.7.0	Shorted Class B SOAR	(See Figure 6)
	<u>Test Points:</u>	
	$I_{C(\text{peak})} = .75\text{A}, V_{CC} = 55\text{V}, R_S = 0.1\Omega$	
	$R_{BB1} = 10\Omega, R_{BB2} = 10\Omega, f = 20\text{Hz},$	
	$T_C = 100^\circ\text{C}$	
4.0.0	<u>Electrical Characteristics</u>	
	Maximum Limits unless otherwise noted.	
	Technique:	
	DC = continuous operation	
	C.T. = Curve Tracer	
	P = 300 μ s Pulse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEV} = 10\mu\text{A}$	$V_{CEV} = 100\text{V}, V_{EB} = 1.5\text{V}, \text{Technique} = \text{C.T.}$
4.1.2	$I_{CB0} = 15\mu\text{A}$	$V_{CB} = 30\text{V}, \text{Technique} = \text{C.T.}$
4.1.3	$I_{CB0} = 750\mu\text{A}$	$V_{CB} = 30\text{V}, T_C = 150^\circ\text{C}, \text{Technique} = \text{C.T.}$
4.1.4	$I_{EB0} = 15\mu\text{A}$	$V_{EB} = 12\text{V}, \text{technique} = \text{C.T.}$
4.1.5	$I_{CEO} = 50\mu\text{A}$	$V_{CEO} = 50\text{V}, \text{technique} = \text{C.T.}$
4.1.6	$V_{CEO} = 55\text{V min.}$	$I_{CEO} = 100\text{mA}, \text{technique} = \text{C.T.}$
4.1.7	$V_{CEV} = 100\text{V}$	$I_C = 100\text{mA}, V_{EB} = 1.5\text{V}, \text{technique} = \text{C.T.}$
4.1.8	$h_{FE} = 35 \text{ min.}$	$V_{CE} = 4\text{V}, I_C = 750\text{mA}, \text{technique} = \text{C.T.}$
	$h_{FE} = 100 \text{ max.}$	
4.1.9	$V_{CE[\text{SAT}]} = .75\text{V}$	$I_C = 0.75\text{A}, I_B = .04\text{A}, \text{technique} = \text{C.T.}$

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.1.10	$V_{CE[SAT]} = 2.5V$	$I_C = 3A, I_B = 300mA, \text{ technique} = C.T.$
4.1.11	$V_{BE[SAT]} = 3.0V$	$I_C = 3A, I_B = 300mA, \text{ technique} = C.T.$
4.1.12	$V_{BE} = 2.5V$	$I_C = 750mA, V_{CE} = 4V, \text{ technique} = C.T.$
4.2.0	Dynamic	
4.2.1	$f_{hfb} = 1MHz \text{ min.}$	$I_C = 5mA, V_{CE} = 28V$
	$f_{hfb} = 10 MHz \text{ max.}$	
4.2.2	$C_{obo} = 175pF$	$V_{CB} = 40V, \text{ MIL-STD -750 method 3236}$
5.0.0	Thermal Characteristics	
5.1.0	$\tau_J = 40mS \text{ min.}$	$I_C = 1A, V_{CE} = 10V, T_C = 25^{\circ}C$ MIL-STD -750 method 3146.1
5.2.0	$\theta_{J-C} = 7.0^{\circ}C/W$	$I_C = 1A, V_{CE} = 10V, T_C = 25^{\circ}C$ MIL-STD -750 method 3136
5.3.0	$\theta_{J-A} = 100^{\circ}C/W$	$I_C = .5A, V_{CE} = 3.5V, \text{ MIL-STD -750}$ method 3151

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

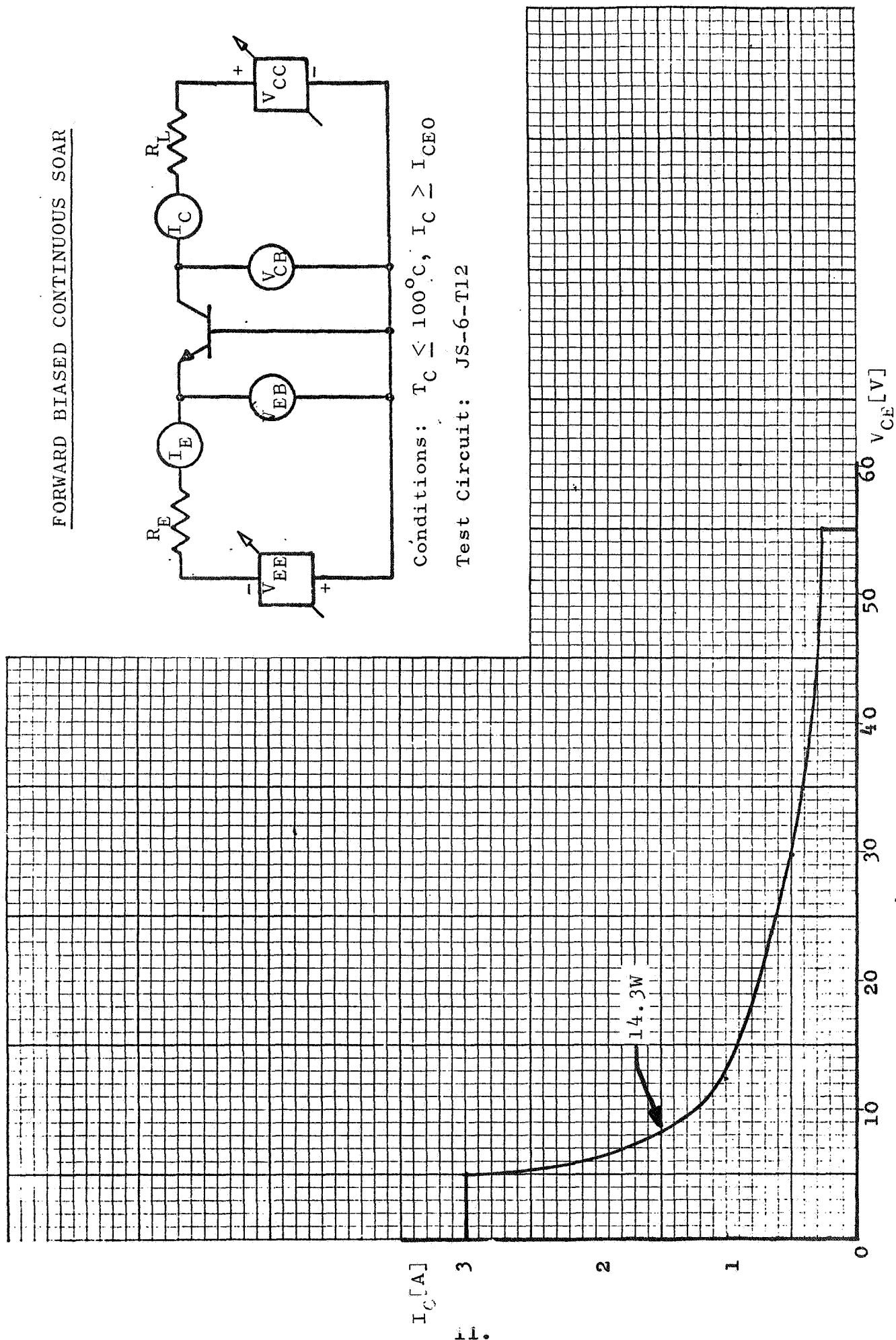
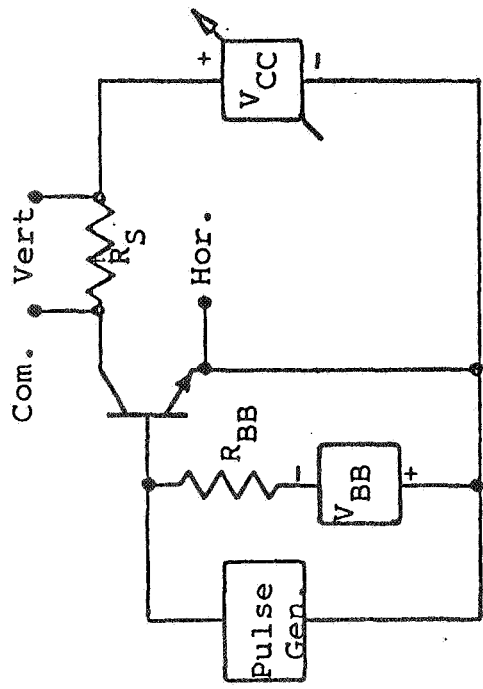


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

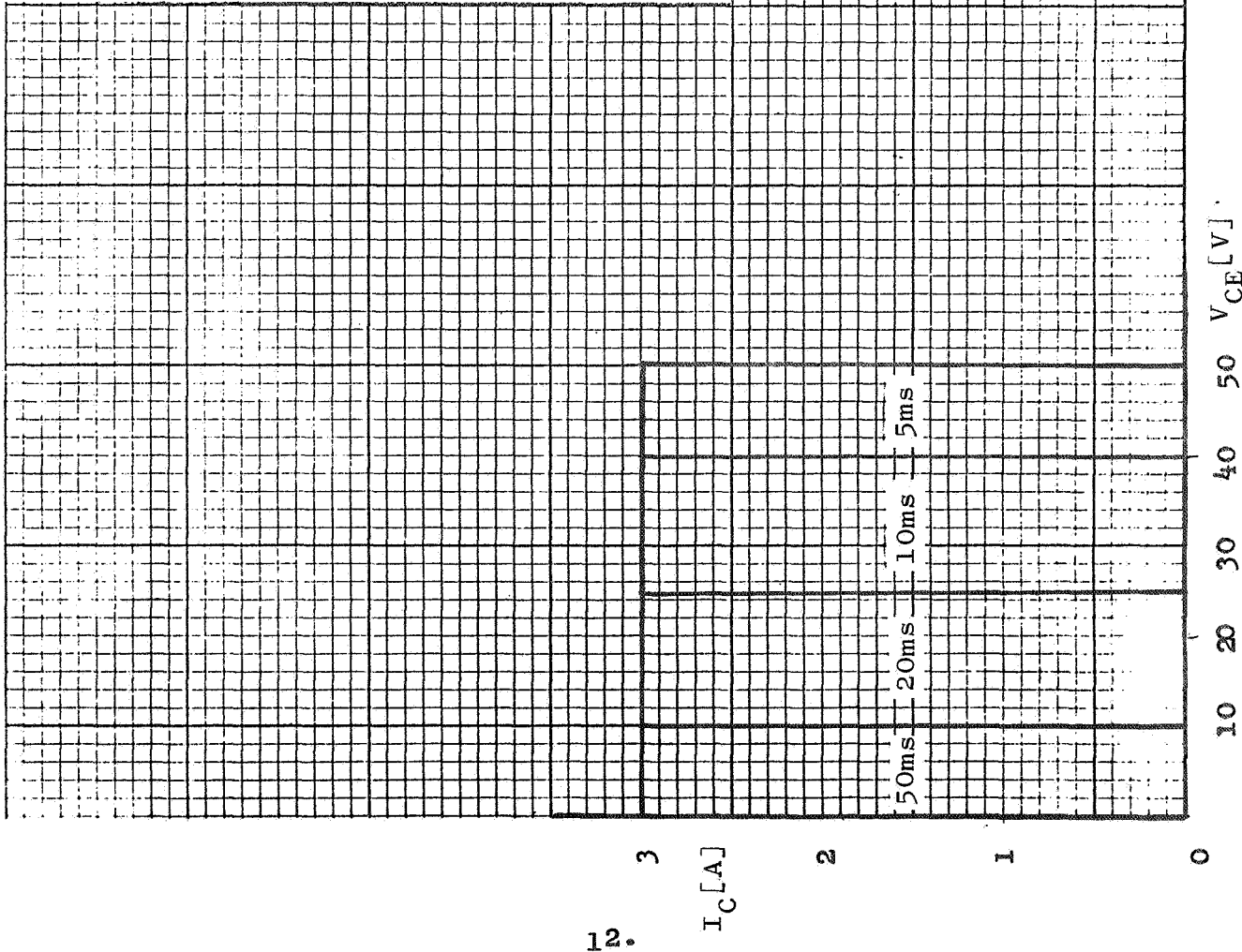
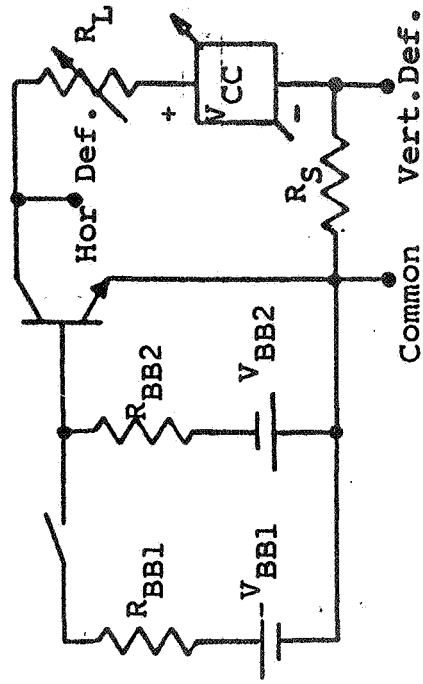


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1

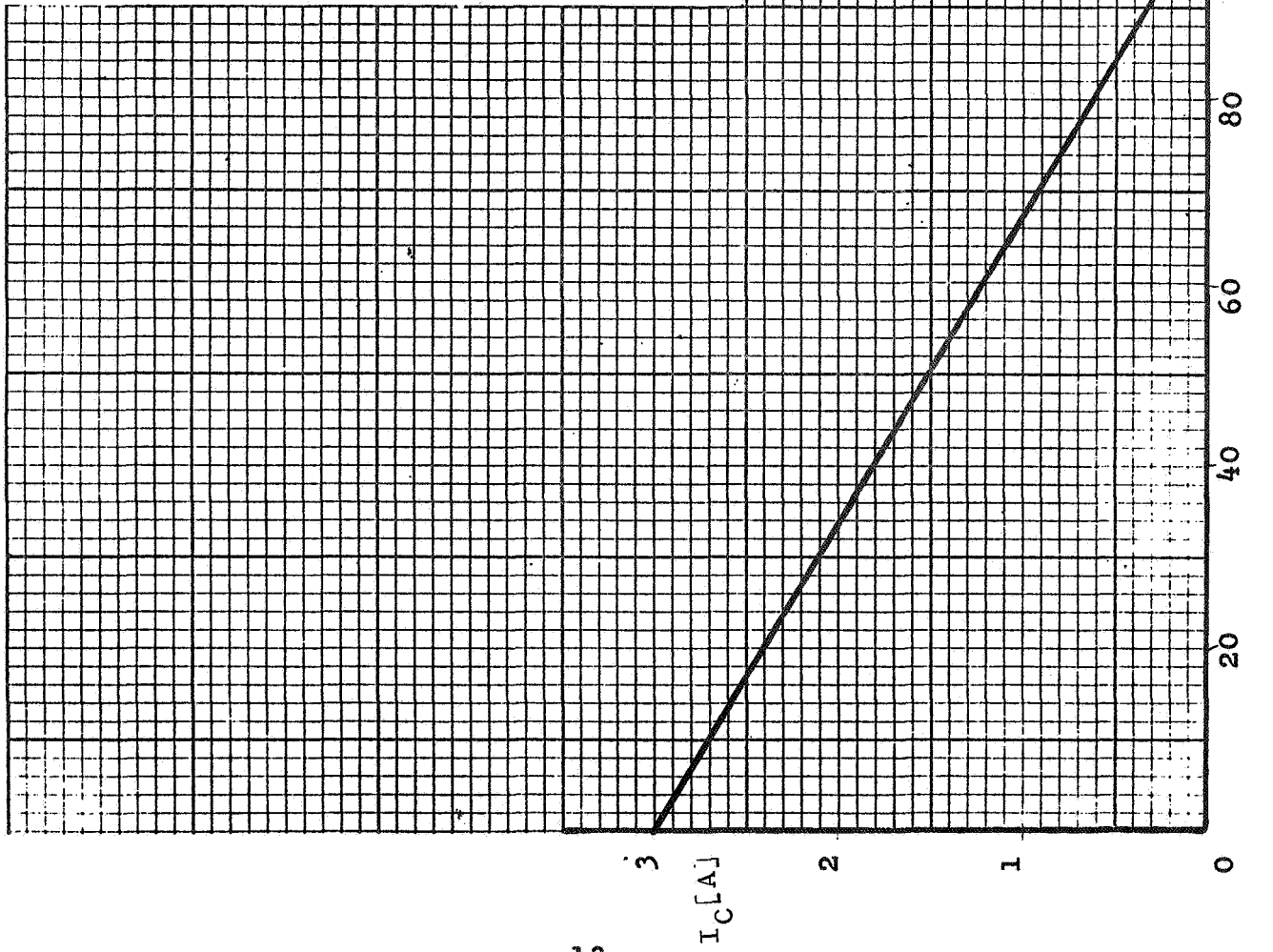
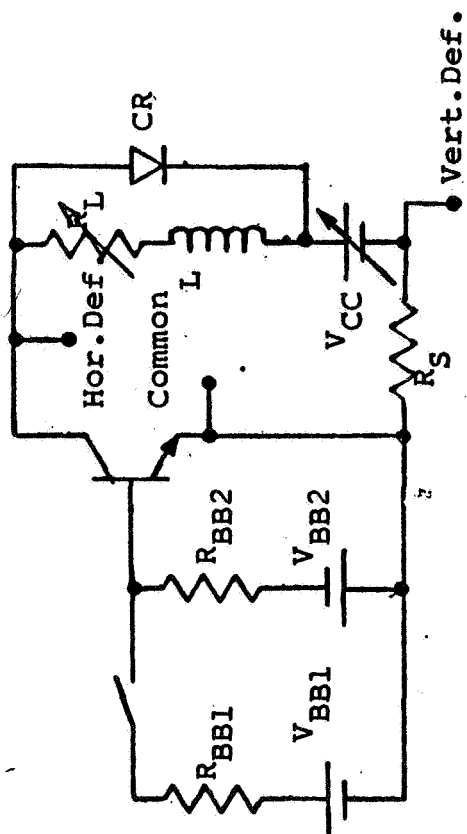


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

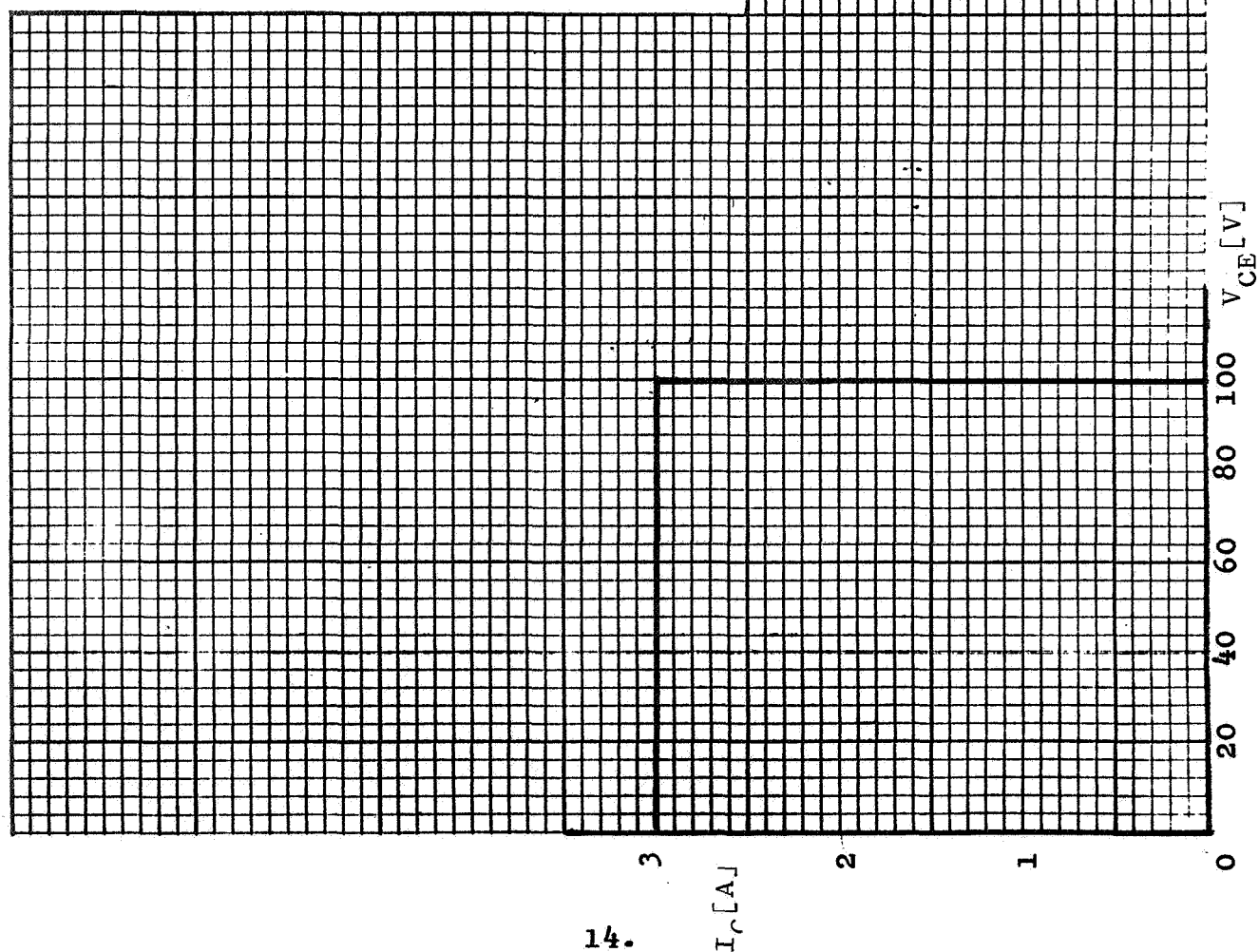
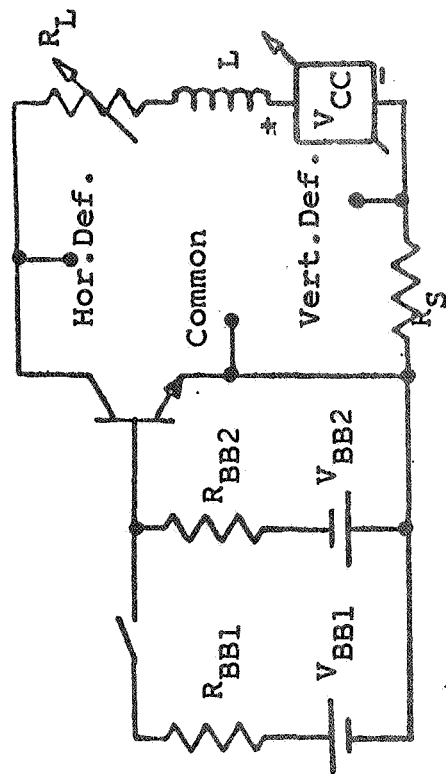


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

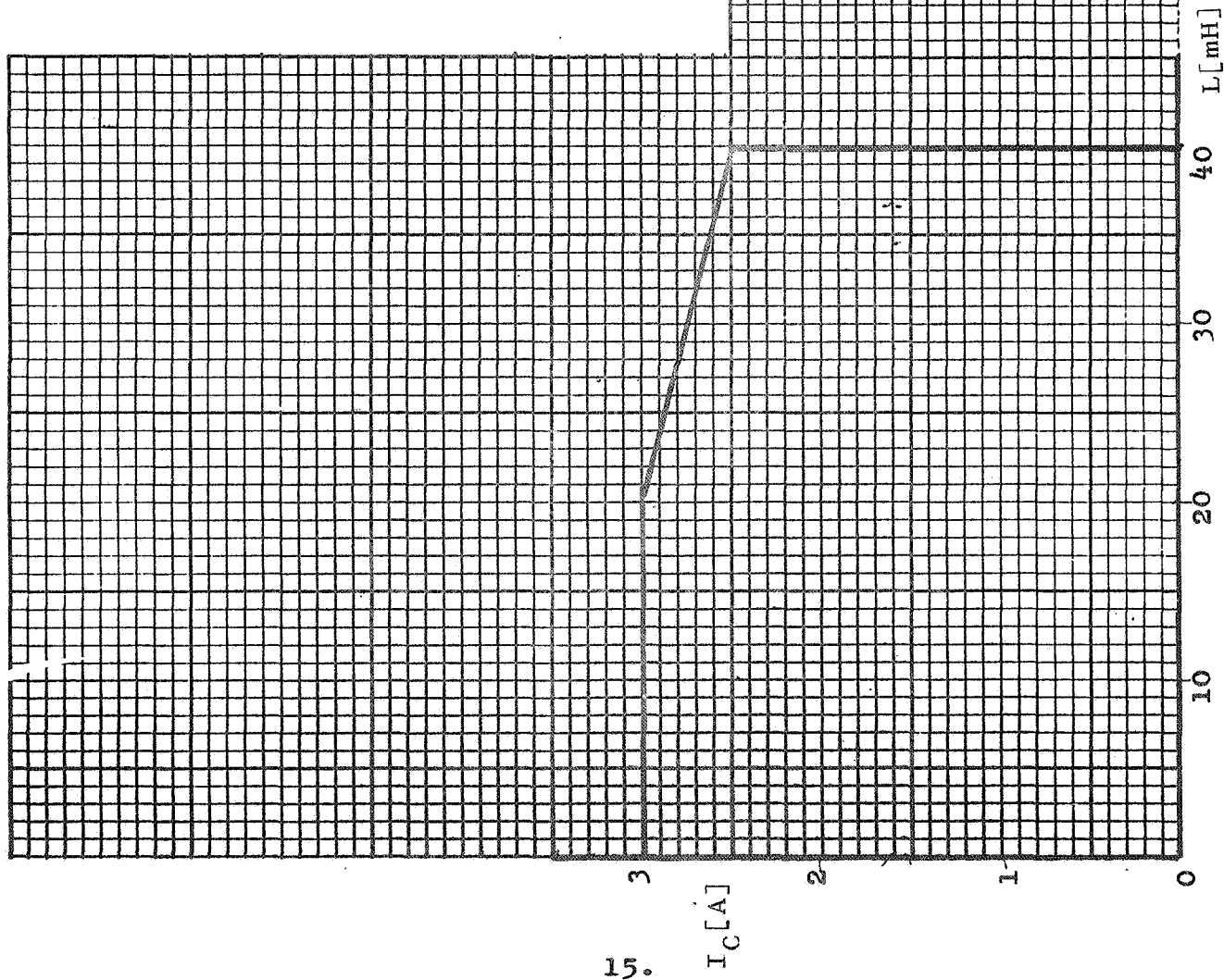


Figure 5

SHORTED CLASS B SOAR

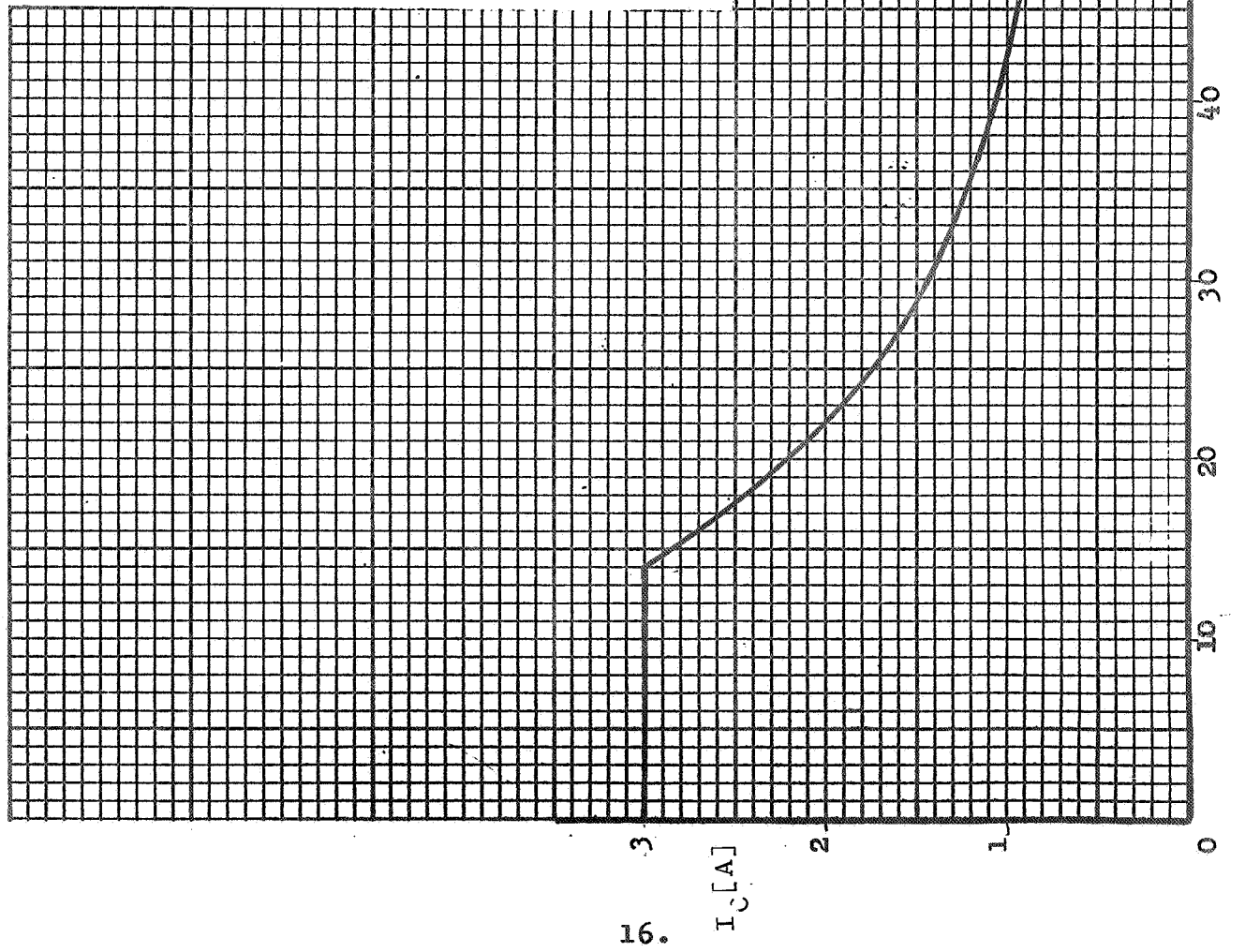
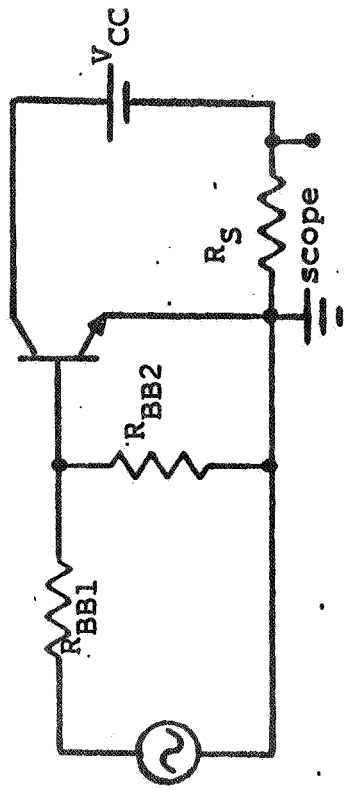


Figure 6

SILICON POWER TRANSISTOR

< Type 2N1724 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer B --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Method and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline -- TO-61	
2.2.0	Terminal Designation	
	1 -- Emitter	
	2 -- Base	
	3 -- Collector	
	case -- Collector	
2.2.1	Maximum Stud Torque -- 30 in. lb.	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.1</u> (JEDEC Suggested Standard: "Test Procedures for Verifications of Maximum Ratings")
	$T_{STG(min)} = -65^{\circ}C$	
3.1.2	$T_{J(max)} = +175^{\circ}C$	<u>JS-6-T2</u>
		$T_C = 100^{\circ}C, V_{CB} = 10V, I_C = 5A$
3.1.3	$T(Lead) = 230^{\circ}C$	Distance from case = $\frac{1}{4}$ in.
		Time = 10s
3.2.0	Voltage	$T_C = 25^{\circ}C$
3.2.1	$V_{CBO} = 120V$	<u>JS-6-T3</u> or MIL-STD-750A Method 3001.1
3.2.2	$V_{EBO} = 10V$	<u>JS-6-T4</u> or MIL-STD-750A Method 3026.1

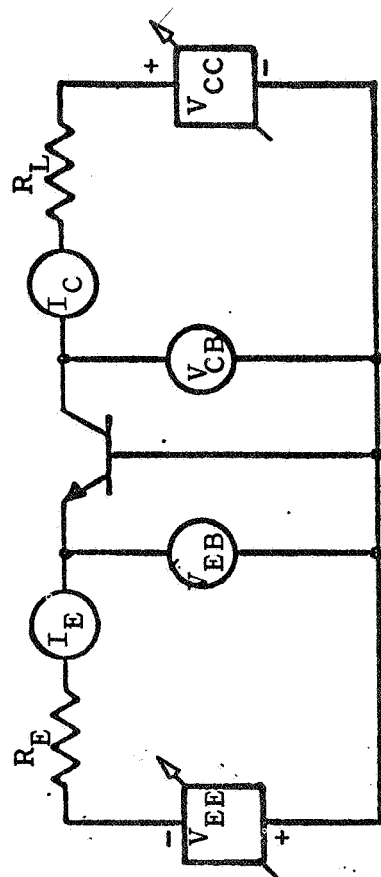
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.2.3 $V_{CEV} = 80V$	<u>JS-6-T5-2.1</u> $I_C (V_{CE} = V_{CEX}) = 7.5A$ $V_{CC} = 80V, R_L = 10.3\Omega, L = 1mH,$ (Miller #7870), $CR = 1N1204, V_{BB1} = 15V,$ $R_{BB1} = 5\Omega, V_{BB2} = 5V, R_{BB2} = 10\Omega,$ Pulse width = 10ms, Duty Cycle = 10%, $R_S = 0.1\Omega$
3.3.0 Current	
3.3.1 $I_C = 5A$	<u>JS-6-T6</u> $I_B = 1A, T_C = 25^{\circ}C$
3.3.2 $I_{CM} = 7.5A$	<u>JS-6-T7</u> $T_C = 25^{\circ}C, R_S = 0.1\Omega, V_{BB} = 5V,$ $R_{BB} = 10\Omega$ Pulse Amplitude = 5.3V, R source = 1Ω Pulse Width = 20ms, Duty Cycle = 20% $t_r \leq 50\mu s, t_f \leq 50\mu s$
3.3.3 $I_B = 2A$	<u>JS-6-T8</u> $T_C = 25^{\circ}C$
3.3.4 $I_E = 6A$	<u>JS-6-T10</u> $I_B = 1A, T_C = 25^{\circ}C$
3.4.0 Power	
3.4.1 $P_T = 50W$	<u>JS-6-T12</u> $T_C = 100^{\circ}C, V_{CB} = 80V, I_C = 625mA$ Derating factor = $0.667W/^{\circ}C$

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.4.2 $P_{TM} = 600W$	<u>JS-6-T13</u> $T_C = 100^{\circ}C$, $V_{CC} = 80V$, $I_C = 7.5A$ $V_{BB} = 5V$, $R_{BB} = 10\Omega$, Pulse Width = 1ms, Duty Cycle = 2%, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> (See Figure 1) <u>Test Point:</u> (See 3.4.1)
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> (See Figure 2) <u>Test Point:</u> $T_C = 100^{\circ}C$, $V_{BB} = 5V$, $R_{BB} = 10\Omega$, $I_C = 7.5A$, $R_S = 0.1\Omega$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, Duty Cycle $\leq 5\%$ 1. For $t_p = 3ms$: $V_{CC} = 55V$ 2. For $t_p = 2ms$: $V_{CC} = 65V$ 3. For $t_p = 1ms$: $V_{CC} = 80V$
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<u>JS-6-T5-2.1</u> with $L = 0$ and CR Disconnected (See Figure 3) <u>Test Points:</u> $T_C = 100^{\circ}C$, Duty Cycle = 10%, Coll. Current, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ $R_{BB1} = 5\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 15V$, $V_{BB2} = 5V$, $I_C = 7.5A$, $V_{CC} = 120V$, $R_L = 15.6\Omega$, $R_S = 0.1\Omega$

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.2 Clamped Inductive Load	<u>JS-6-T5-2.1</u> (See Figure 4) <u>Test Point:</u> (See 3.2.3)
3.6.3 Unclamped Inductive Load	<u>JS-6-T5-2.1</u> and CR disconnected (See Figure 5) <u>Test Point:</u> [1.] $R_{BB1} = 5\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 15V$, $V_{BB2} = 5V$, $L = 5mH$, 0.03Ω (Stancor #C-2689) $I_C = 7.5A$, $V_{CC} = 18V$, $R_L = 2\Omega$, $R_S = 0.1\Omega$, $d \leq 10\%$, $T_C = 25^{\circ}C$, $t_p = 10ms$ [2.] $R_{BB1} = 5\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 8V$, $V_{BB2} = 5V$, $L = 20mH$, 0.22Ω (two in series Stancor #C-2688) $I_C = 2.5A$, $V_{CC} = 13.5V$, $R_L = 5\Omega$, $R_S = 0.1\Omega$, $T_C = 25^{\circ}C$, $d \leq 10\%$, $t_p = 10ms$
3.7.0 Shorted Class B SOAR (See Figure 6)	<u>Test Point:</u> $I_C \text{ peak} = 1.88A$, $V_{CC} = 80V$, $R_S = 0.1\Omega$, $R_{BB1} = 1\Omega$, $R_{BB2} = 10\Omega$, $f=20Hz$, $T_C = 100^{\circ}C$ $T_C = 25^{\circ}C$ (unless otherwise noted)
4.0.0 <u>Electrical Characteristics</u>	
Maximum limits unless otherwise noted	
Technique:	
DC - Continuous Operation	
C.T. - Curve Tracer	
P - 300 μs Pulse, 2% Duty Cycle	

Item	Test Methods and Test Conditions	
4.1.0	Static	
4.1.1	$I_{CBO} = 0.5\text{mA}$	$V_{CB} = 3\text{V}$ Technique - C.T.
4.1.2	$V_{EBF} = 10\text{V}$	$V_{CB} = 80\text{V}$ Technique - C.T.
4.1.3	$I_{CES} = 1.0\text{mA}$	$V_{CE} = 60\text{V}$ Technique - C.T.
4.1.4	$I_{CES} = 2.0\text{mA}$	$T_C = 150^{\circ}\text{C}$, $V_{CE} = 60\text{V}$ Technique - C.T.
4.1.5	$I_{CES} = 10\text{mA}$	$T_C = 150^{\circ}\text{C}$, $V_{CE} = 120\text{V}$ Technique - C.T.
4.1.6	$I_{CEO} = 10\text{mA}$	$T_C = 25^{\circ}\text{C}$, $V_{CE} = 80\text{V}$ Technique - C.T.
4.1.7	$I_{EBO} = 10\text{mA}$	$V_{EB} = 10\text{V}$ Technique - C.T.
4.1.8	$V_{CEO} = 80\text{V min.}$	$I_C = 0.2\text{A}$ Technique - C.T.
4.1.9	$h_{FE} = 20 \text{ min}$	$V_{CE} = 15\text{V}$, $I_C = 0.1\text{A}$ Technique - C.T.
4.1.10	$h_{FE} = 20 \text{ min, } 90 \text{ max}$	$V_{CE} = 15\text{V}$, $I_C = 2\text{A}$ Technique - P
4.1.11	$h_{FE} = 10 \text{ min}$	$V_{CE} = 2\text{V}$, $I_C = 5\text{A}$ Technique - P
4.1.12	$V_{CE(\text{sat})} = 1\text{V}$	$I_C = 2\text{A}$, $I_B = 0.2\text{A}$, Technique - C.T.
4.1.13	$V_{CE(\text{sat})} = 2\text{V}$	$I_C = 7.5\text{A}$, $I_B = 1.5\text{A}$ Technique - P
4.1.14	$V_{BE(\text{sat})} = 2\text{V}$	$I_C = 2\text{A}$, $I_B = 0.2\text{A}$, Technique - C.T.
4.1.15	$V_{BE(\text{sat})} = 2.5\text{V}$	$I_C = 7.5\text{A}$, $I_B = 1.5\text{A}$ Technique - P
4.2.0	Dynamic	
4.2.1	$h_{fe} = 2.0 \text{ min}$ $= 10.0 \text{ max}$	$V_{CE} = 15\text{V}$, $I_C = 0.5\text{A}$, $f = 5 \text{ MHz}$
4.2.2	$C_{obo} = 550 \text{ pF max}$	$V_{CB} = 15\text{V}$, $f = 1\text{MHz}$
5.0.0	Thermal Characteristics	
5.1.0	$\tau_J \text{ min} = 10\text{ms}$	$V_{CE} = 10\text{V}$, $I_C = 2\text{A}$, $T_C = 25^{\circ}\text{C}$, MIL-STD-750, Method 3146.1
5.2.0	$\theta_{JC} = 1.5^{\circ}\text{C/W}$	$V_{CE} = 10\text{V}$, $I_C = 2\text{A}$, $T_C = 25^{\circ}\text{C}$ MIL-STD-750, Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

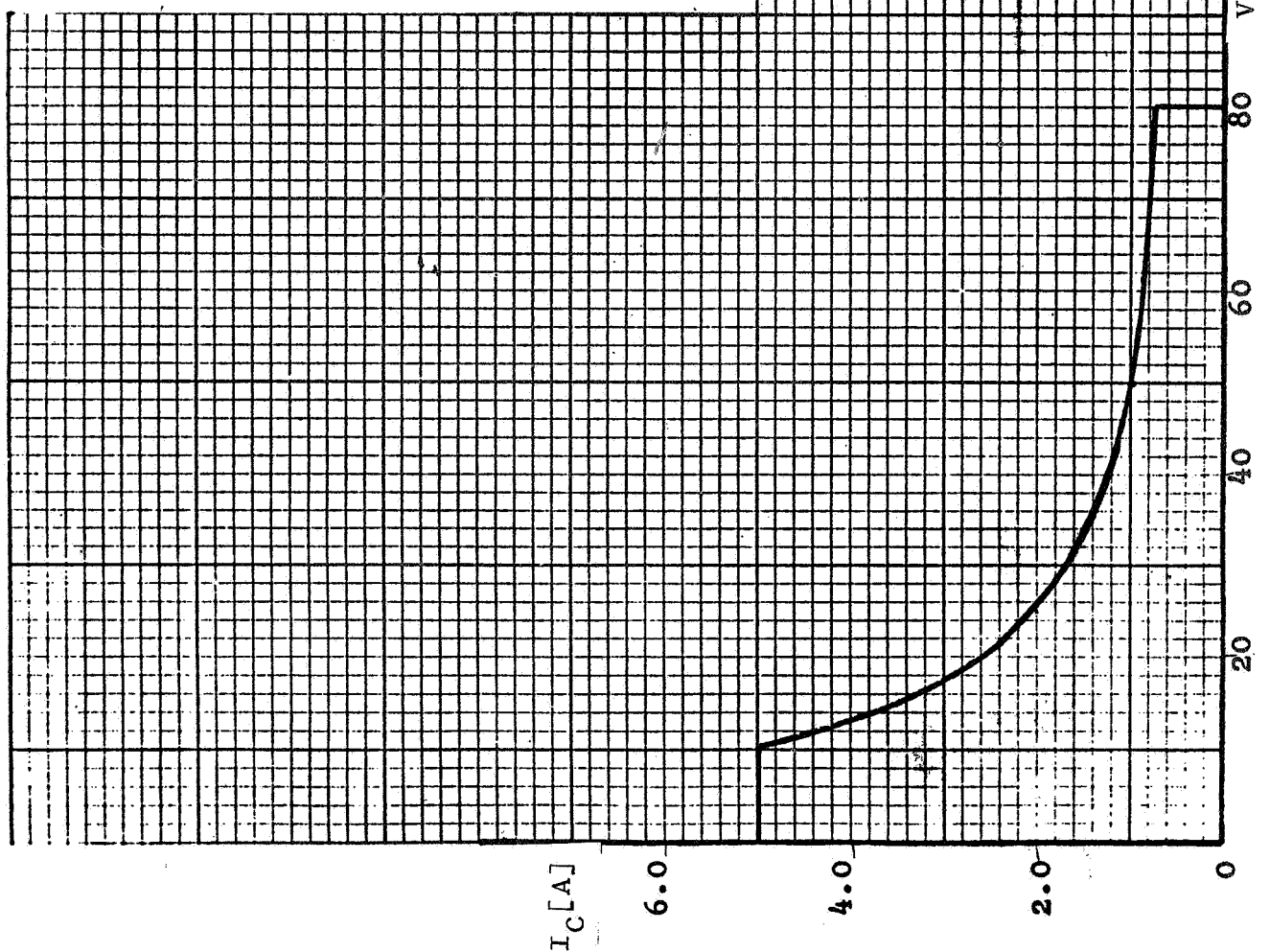
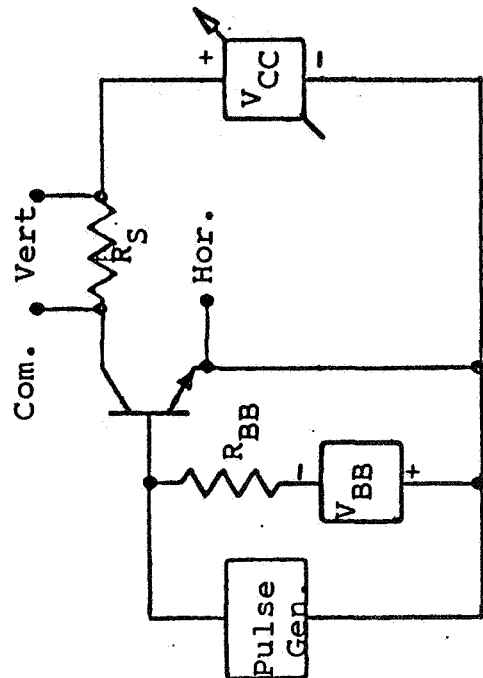


Figure 1

PULSED FORWARD BIASED SOAR

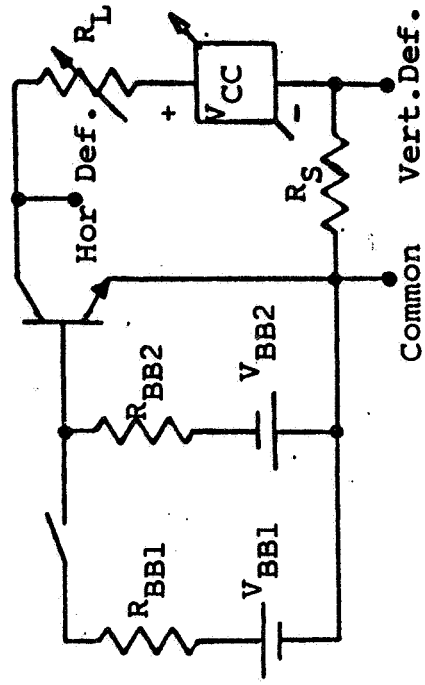
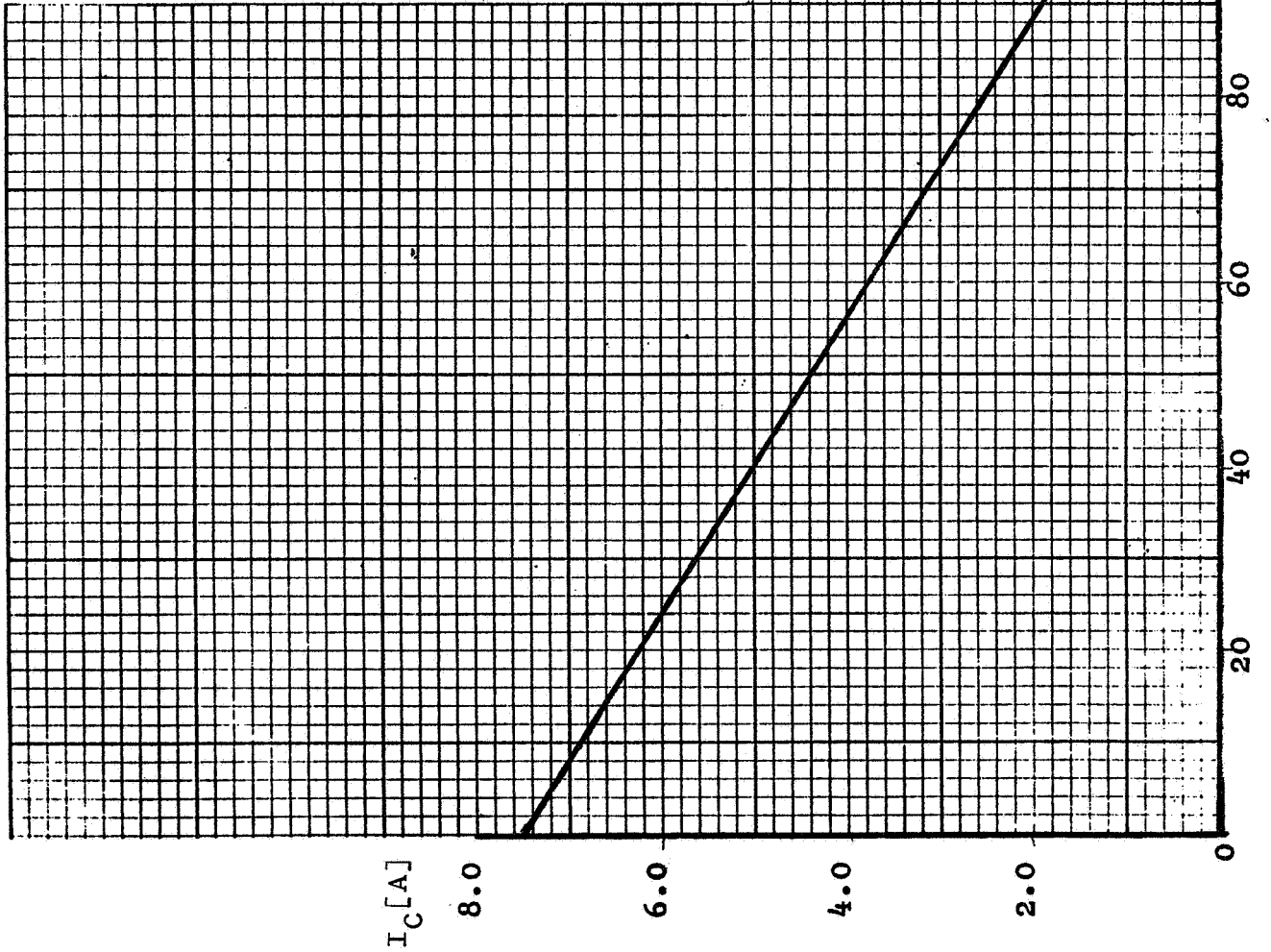


Test Circuit: JS-6-T14



Figure 2

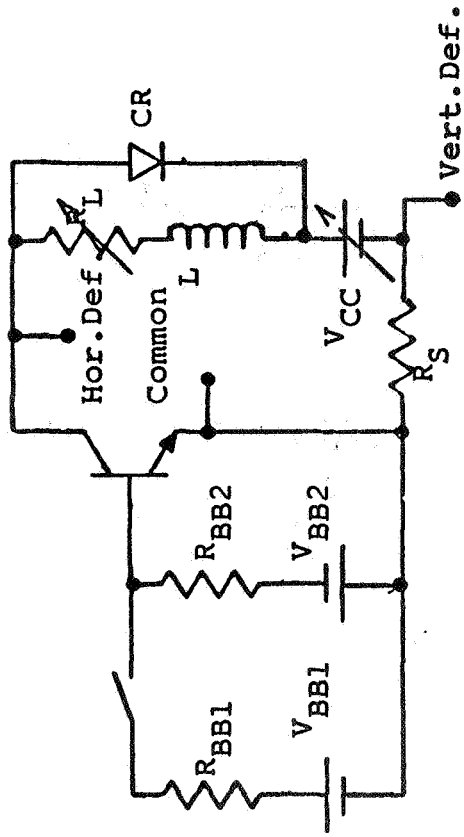
SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1

Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

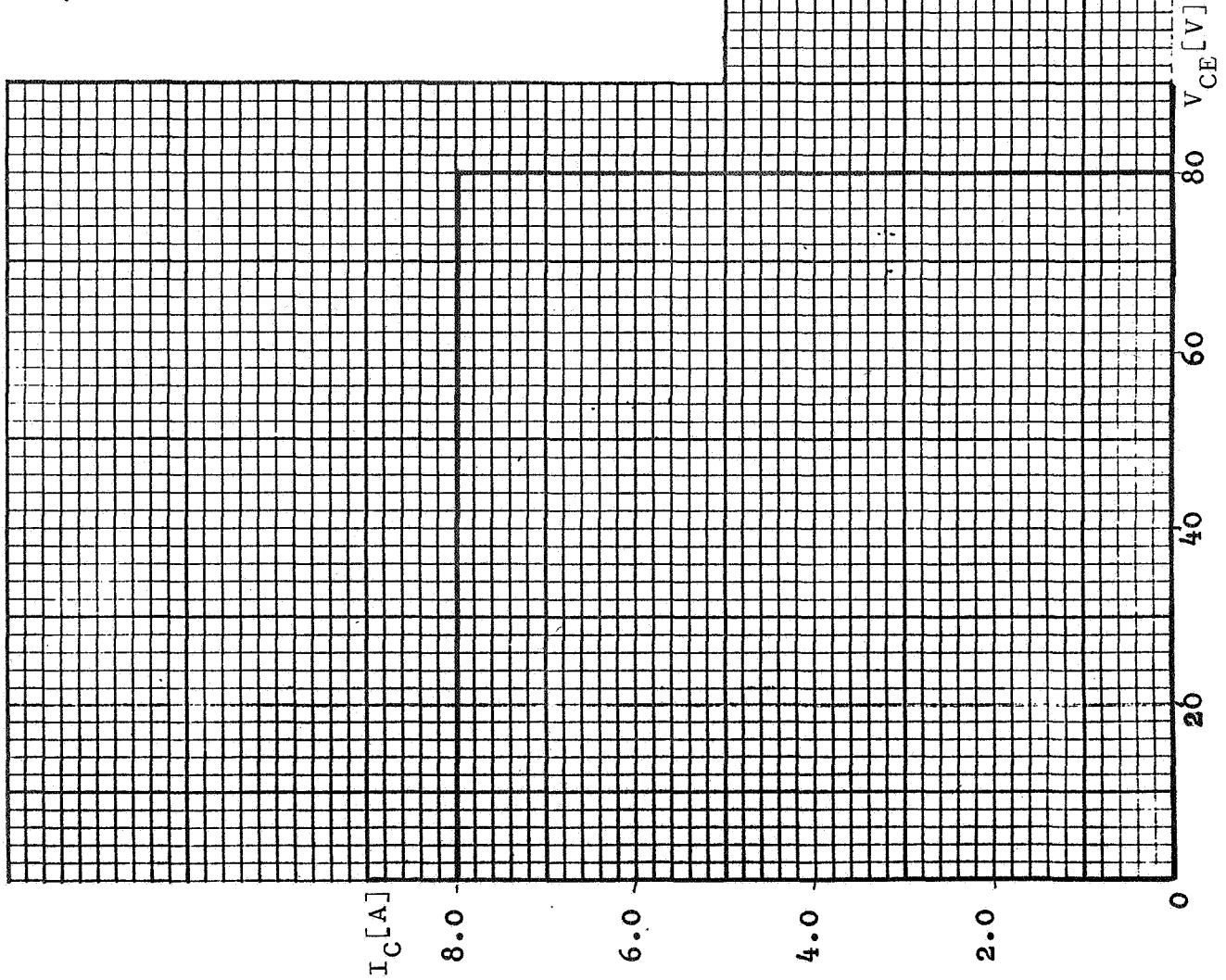
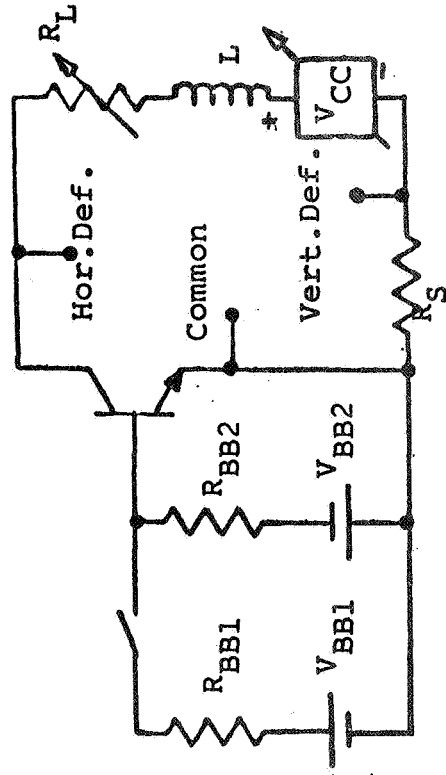


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

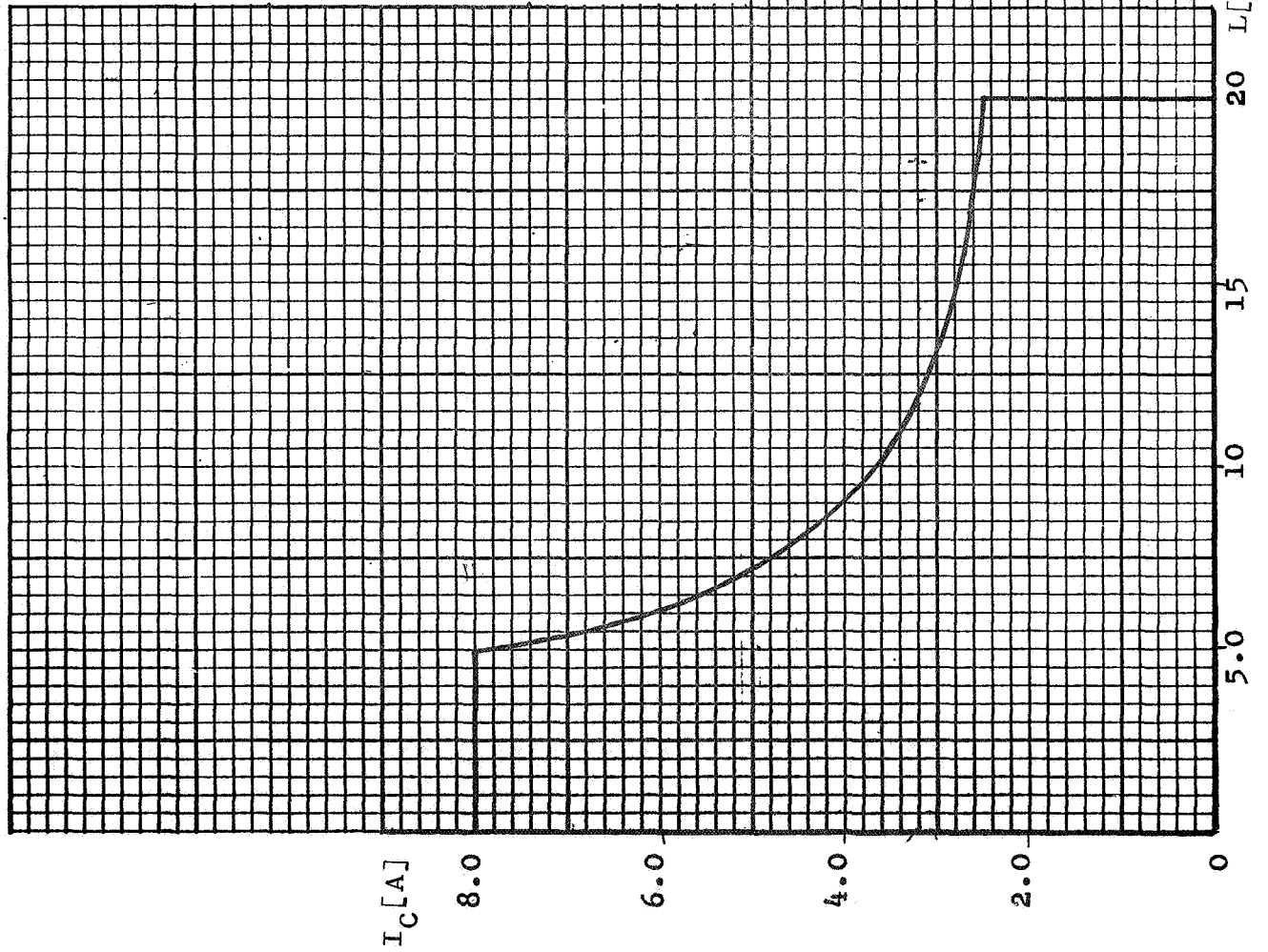


Figure 5

SHORTED CLASS B SOAR

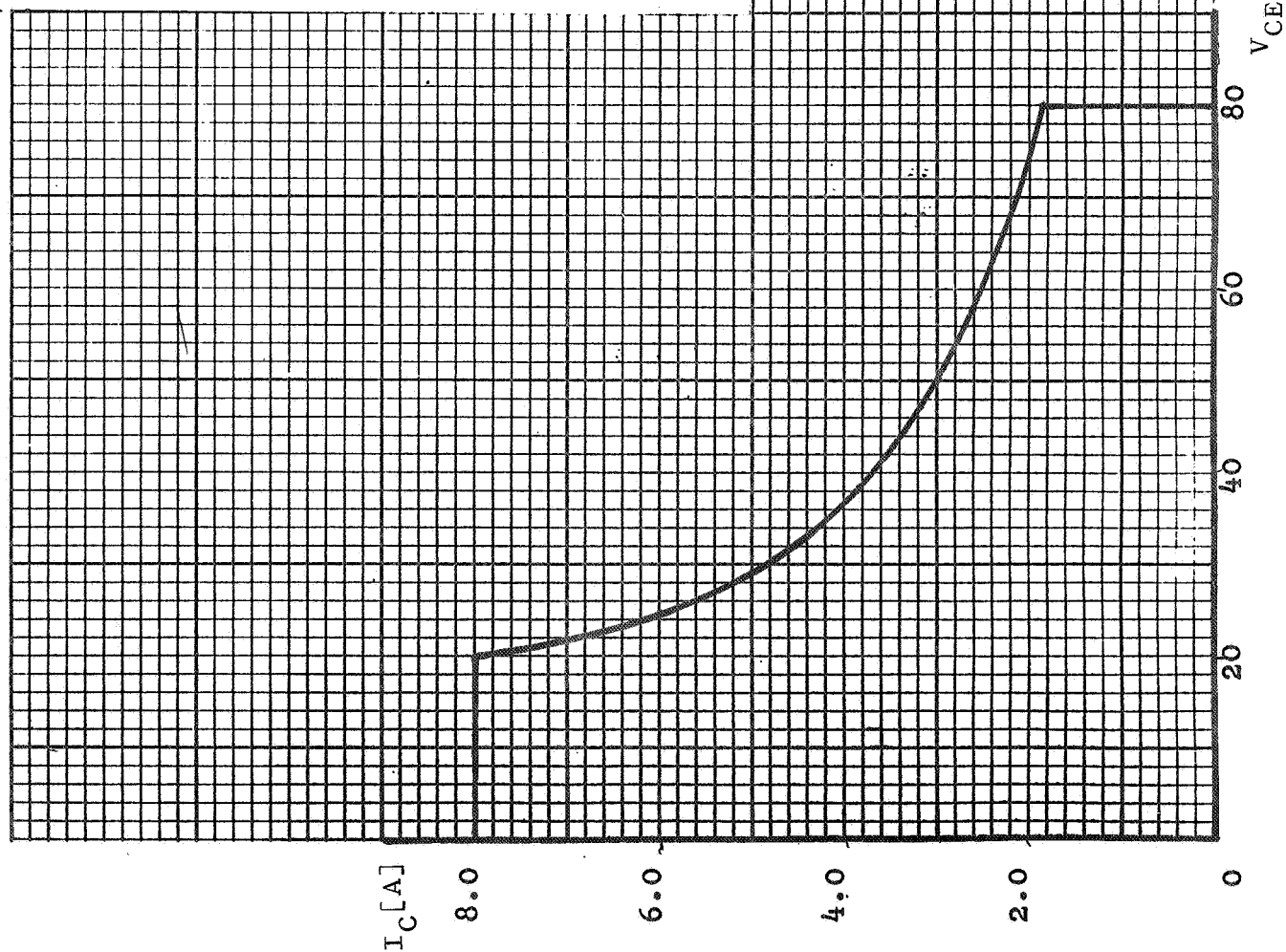
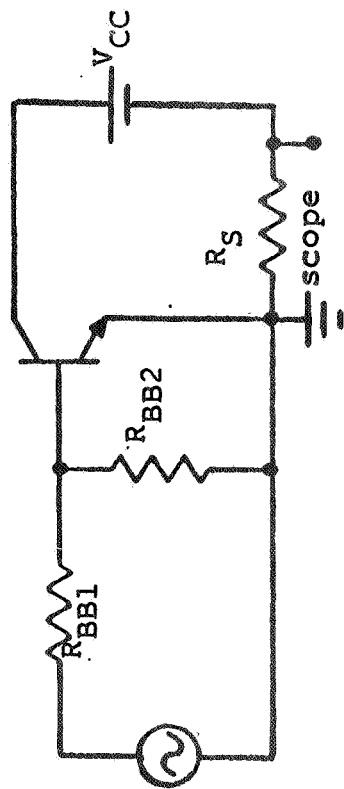


Figure 6

SILICON POWER TRANSISTOR

< Type 2N1016D >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer C --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline -- TO-82	
2.2.0	Terminal Designation	
	1 -- Base	
	2 -- Emitter	
	3 -- Collector	
	Case -- Collector	
2.2.1	Maximum Stud Torque -- 50 in lbs.	
	Minimum Stud Torque -- 40 in lbs.	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +150^{\circ}C$	JS-6-T1.1 (JEDEC Suggested Standard: "Test Procedures for Veri- fications of Maximum Ratings")
	$T_{STG(min)} = -65^{\circ}C$	JS-6-T1.2
3.1.2	$T_J = 150^{\circ}C$	JS-6-T2
		$T_C = 100^{\circ}C$, $V_{CB} = 100V$, $I_C = 0.71A$
3.1.3	$T(Lead) = 230^{\circ}C$	Distance from case = 1/4 in., Time = 10s
3.2.0	Voltage	
3.2.1	$V_{CBO} = 200V$	JS-6-T3 or MIL-STD-750A Method 3001.1
3.2.2	$V_{EBO} = 25V$	JS-6-T4 or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 200V$	JS-6-T5-2.1
	$I_C (V_{CE} = V_{CEX}) = 7.5A$, $V_{CC} = 200V$	
	$R_L = 26.6\Omega$, $L = 1mH^*$, CR - 1N1204.	
	*Miller No. 7871 in weries with Miller No. 7825-3	

<u>Item</u>		<u>Test Methods and Test Conditions</u>
3.2.3	continued	$V_{BB1} = 12.5V$, $R_{BB1} = 3\Omega$, $V_{BB2} = 3V$, $R_{BB2} = 3\Omega$ Duty Cycle = 1%, $t_p = 1 \text{ ms}$, $R_s = 0.1\Omega$
3.3.0	Current	
3.3.1	$I_C = 7.5A$	<u>JS-6-T6</u> $I_B = 1.5A$, $T_C = 25^\circ C$
3.3.2	$I_B = 5A$	<u>JS-6-T8</u> $T_C = 25^\circ C$
3.3.3	$I_E = 9.0A$	<u>JS-6-T10</u> $I_B = 1.5A$, $T_C = 25^\circ C$
3.4.0	Power	
3.4.1	$P_T = 71.4W$	<u>JS-6-T12</u> $T_C = 100^\circ C$, $V_{CB} = 200V$, $I_C = 0.355A$ Derating factor = $1.43 \text{ W}/^\circ C$
3.4.2	$P_{TM} = I_C V_{CC} = 1125W$	<u>JS-6-T13</u> $T_C = 100^\circ C$, $V_{CC} = 150V$, $V_{BB} = 3V$ $R_{BB} = 3\Omega$, $I_C = 7.5A$, Pulse Width $1ms$ Duty Cycle = 1%, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ of Collector Current
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> (See Figure 1) Test Point: (See 3.4.1)
3.5.2	Pulsed Forward Biased SOAR	<u>JS-6-T14</u> (See Figure 2) <u>Test Points:</u> $T_C = 100^\circ C$, $V_{BB} = 3V$, $R_{BB} = 3\Omega$, Coll. Cu $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, $I_C = 7.5A$ Duty Cycle $\leq 1\%$, $R_s = 0.1\Omega$

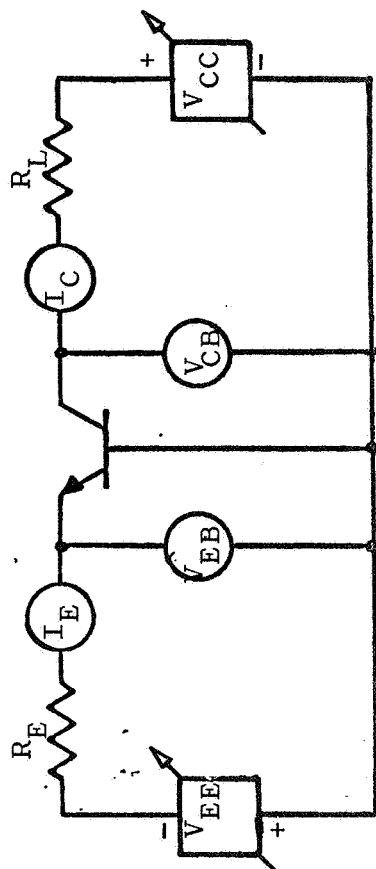
<u>Item</u>		<u>Test Methods and Test Conditions</u>
3.5.2	Continued	1. For $t_p = 20\text{ms}$: $V_{CC} = 90\text{V}$ 2. For $t_p = 10\text{ms}$: $V_{CC} = 110\text{V}$ 3. For $t_p = 5\text{ms}$: $V_{CC} = 125\text{V}$ 4. For $t_p = 1\text{ms}$: $V_{CC} = 150\text{V}$
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	<u>JS-6-T5.1</u> with $L = 0$ and CR disconnected (See Figure 3) <u>Test Points:</u> $R_{BB1} = 3\Omega$, $R_{BB2} = 3\Omega$, $V_{BB1} = 12.5\text{V}$ $V_{BB2} = 3\text{V}$, $T_C = 100^\circ\text{C}$, $t_f \leq 50\mu\text{s}$ Coll. Current, $t_r \leq 50\mu\text{s}$ Coll. Current, $R_S = 0.1\Omega$, $I_C = 7.5\text{A}$, $V_{CC} = 200\text{V}$
3.6.2	Clamped Inductive Load	<u>JS-6-T5.1</u> (See Figure 4) <u>Test Points:</u> (See 3.2.3)
3.6.3	Unclamped Inductive Load	<u>JS-6-T5-2.1</u> and CR disconnected (See Figure 5) <u>Test Points:</u>
		1. $V_{BB1} = 12.5\text{V}$ $L = 1.4\text{mH}^*$ $R_{BB1} = 3\Omega$ $R_L = 3\Omega$ $V_{BB2} = 3\text{V}$ $V_{CC} = 25\text{V}$ $R_{BB2} = 3\Omega$ $f = 60\text{Hz}$ $R_S = 0.1\Omega$ $d = 10\%$ 2. $V_{BB1} = 3.0\text{V}$ $L = 10\text{mH}^{**}$ $R_{BB1} = 10\Omega$ $R_L = 7.5\Omega$ $V_{BB2} = 1.5\text{V}$ $V_{CC} = 25.0\text{V}$ $R_{BB2} = 30\Omega$ $f = 60\text{Hz}$ $R_S = 0.1\Omega$ $d = 30\%$

*Miller #7871 in series with Miller
 #7825-3 **Series Stancor C-2688

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
3.7.0	Shorted Class B SOAR	(See Figure 6)
		<u>Test Points:</u>
		$I_C \text{ peak} = 1.1\text{A}, V_{CC} = 200\text{V}, R_S = 0.1\Omega$
		$R_{BB_1} = 5\Omega, R_{BB_2} = 10\Omega, f = 20\text{Hz},$
		$T_C = 100^\circ\text{C}$
4.0.0	<u>Electrical</u> <u>Characteristics</u>	$T_C = 25^\circ\text{C}$ (unless otherwise noted)
	Maximum limits unless otherwise noted	
	Technique:	
	DC - Continuous Operation	
	C.T. - Curve Tracer	
	P - 300 μs Pluse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEX} = 20\text{mA}$	$V_{CEX} = 200\text{V}, V_{BE} = -1.5\text{V},$
		Technique - C.T., $T_C = 150^\circ\text{C}$
	$I_{CES} = 100\mu\text{A}$	$V_{CE} = 240\text{V}$
		Technique - C.T.
4.1.2	$I_{CEO} = 10\text{mA}$	$V_{CEO} = 200\text{V},$ Technique - C.T.
4.1.3	$I_{EBO} = 20\text{mA}$	$V_{EBO} = 25\text{V},$ Technique - C.T.
		$T_C = 150^\circ\text{C}$
4.1.4	$V_{CEO} = 200\text{V min}$	<u>JS-6-T5-2.1</u> and CR disconnected
		$I_C = 1\text{A}, R_{BB_1} = 3\Omega, V_{BB_1} = 3\text{V},$
		$R_{BB_2} = \infty\Omega, d = 50\%, f = 60\text{Hz}$
		$L = 10\text{mH}, R_L = 0.1\Omega, R_S = 0.1\Omega$
		Adjust V_{CC} for specified I_C .

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.1.5	$h_{FE} = 10 \text{ min}$	$V_{CE} = 4V, I_C = 5A, \text{Technique} - C.T.$
	$h_{FE} = 7.5 \text{ min}$	$V_{CE} = 4V, I_C = 7.5A \text{Technique} - C.T.$
4.1.6	$V_{CE(sat)} = 2.5V$	$I_C = 5A, I_B = .75A, \text{Technique} - C.T.$
4.2.0	Dynamic	
4.2.1	$f_{hfe} = 10KHz \text{ min},$ $40KHz \text{ max}$	$I_C = 1A, V_{CE} = 5V$
5.0.0	Thermal Characteristics	
5.1.0	$T_J \text{ min} = 70ms$	$I_C = 2A, V_{CE} = 10V, T_C = 25^{\circ}C$ MIL-STD-750 Method 3146.1
5.2.0	$\theta_{JC} = 0.7^{\circ}C/W$	$I_C = 2A, V_{CE} = 10V, T_C = 25^{\circ}C$ MIL-STD-750 Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

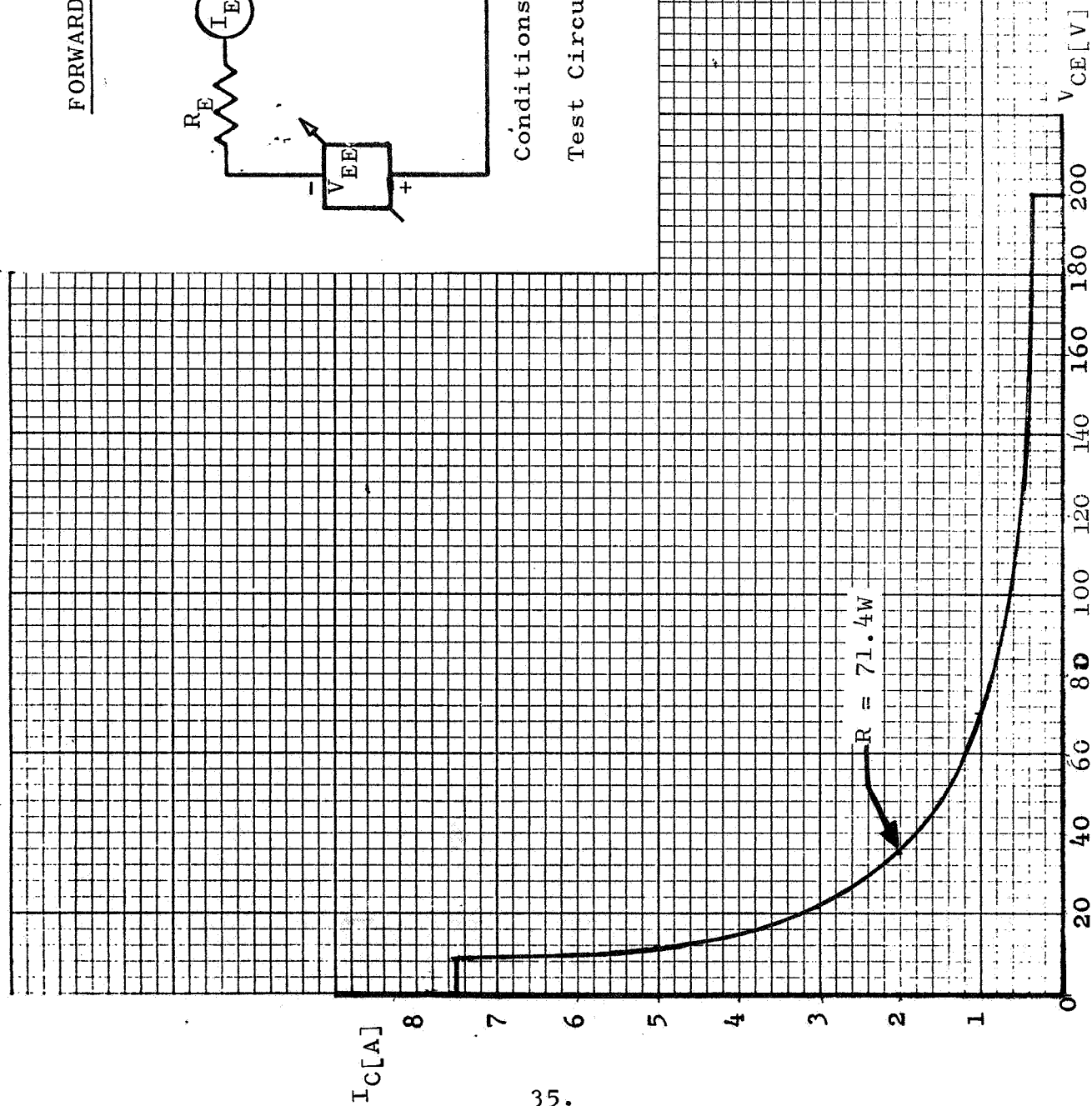
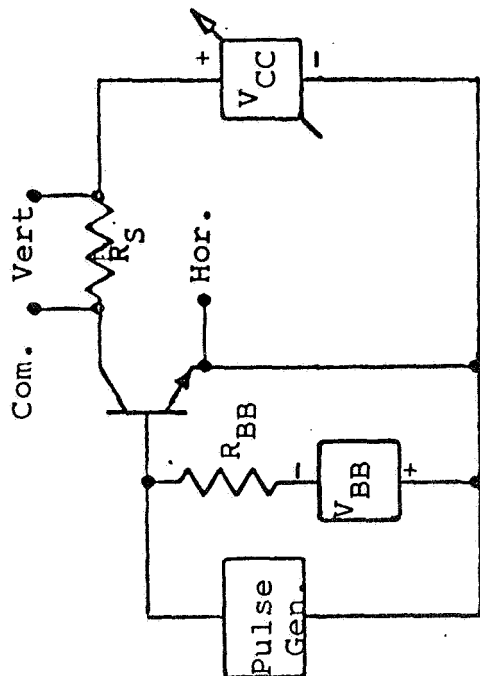


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

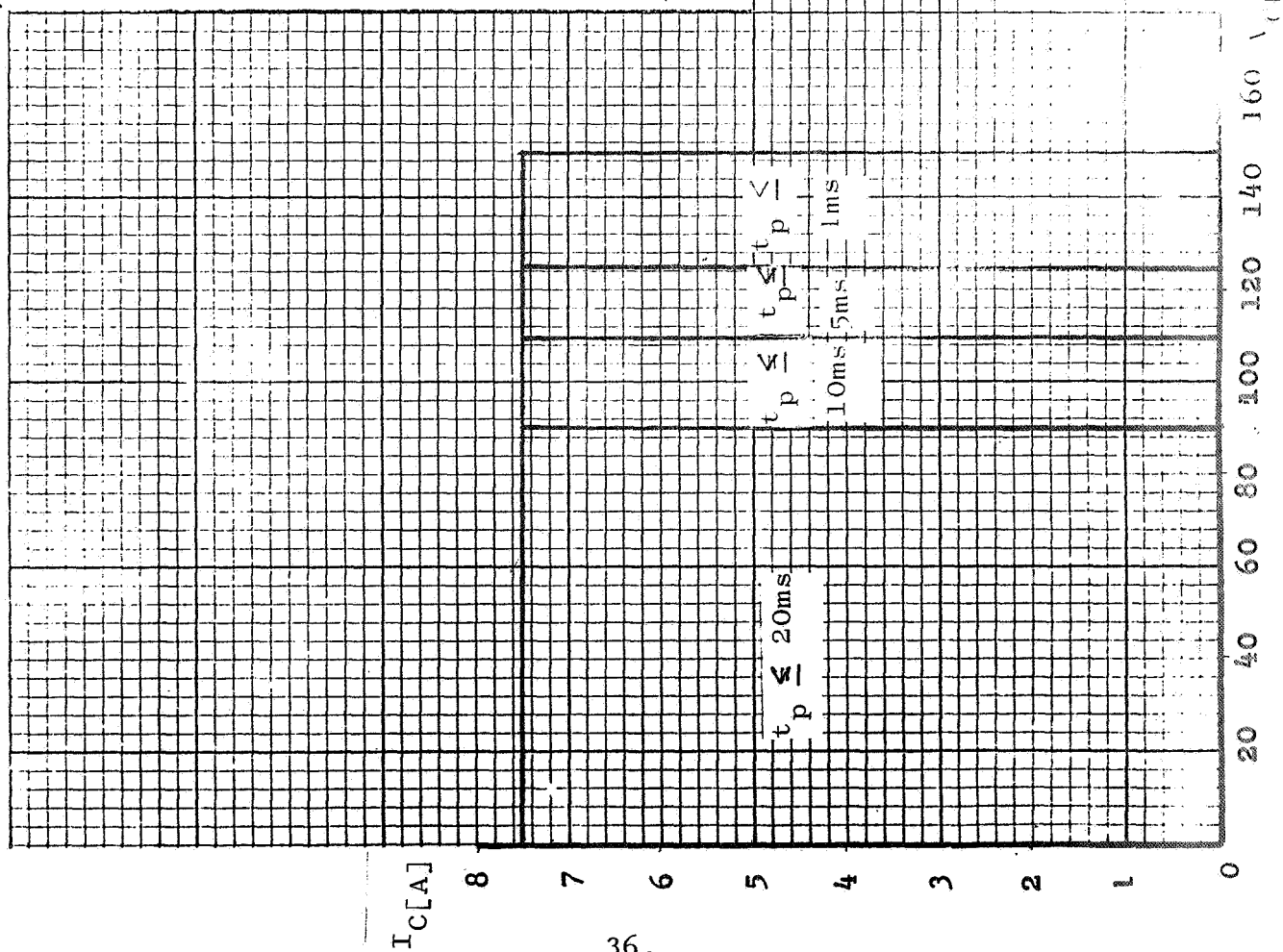


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

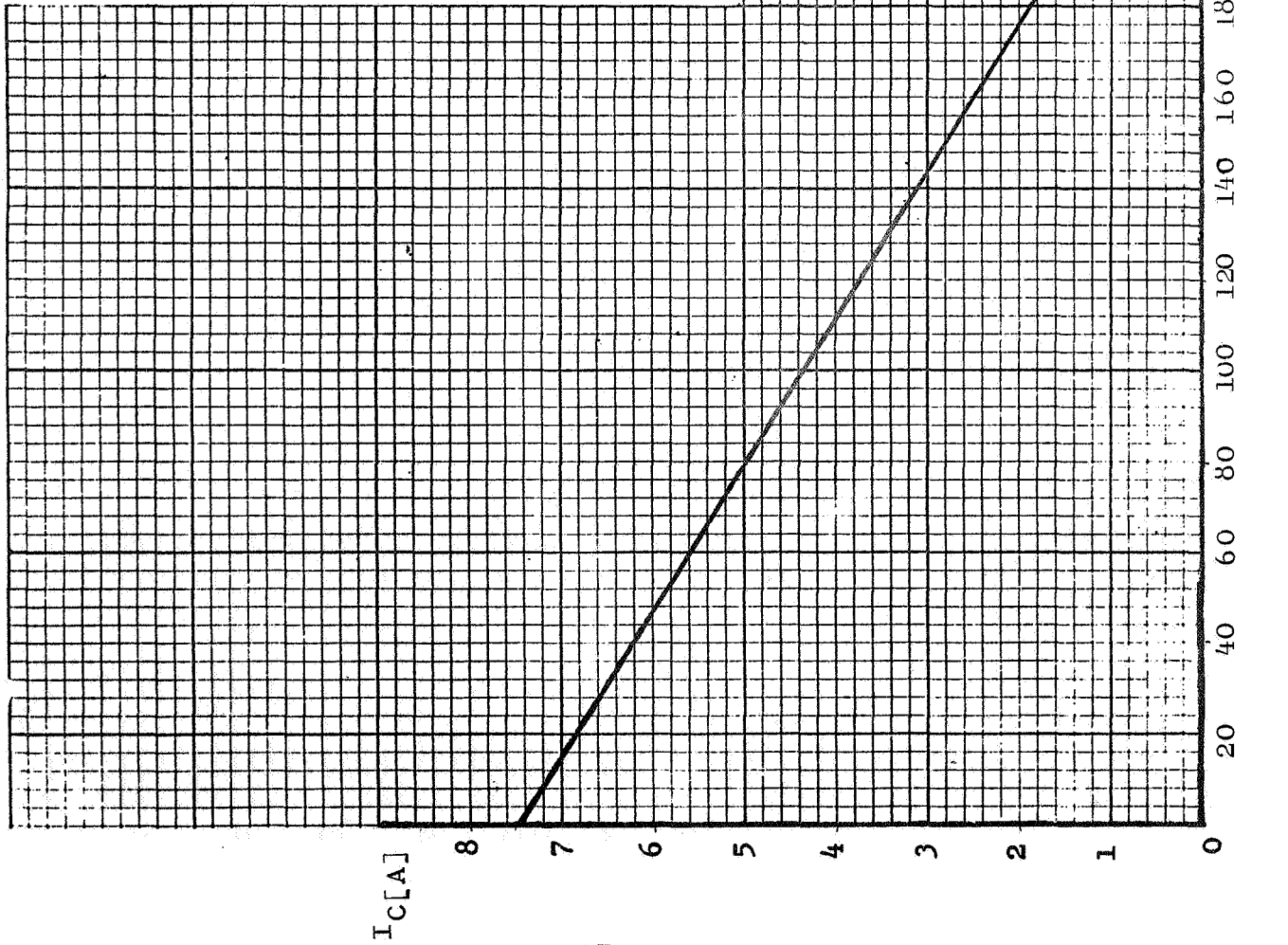
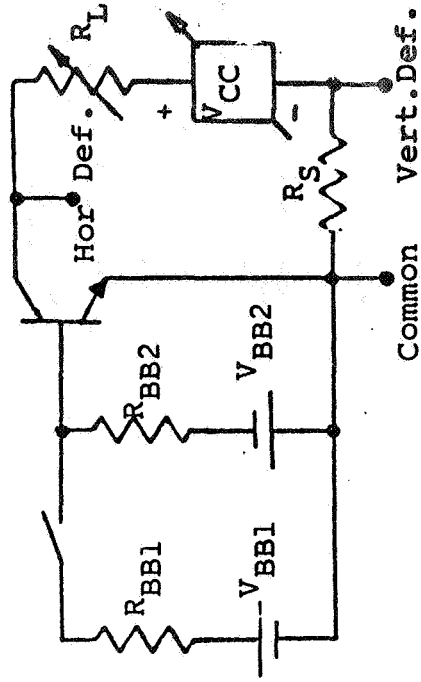
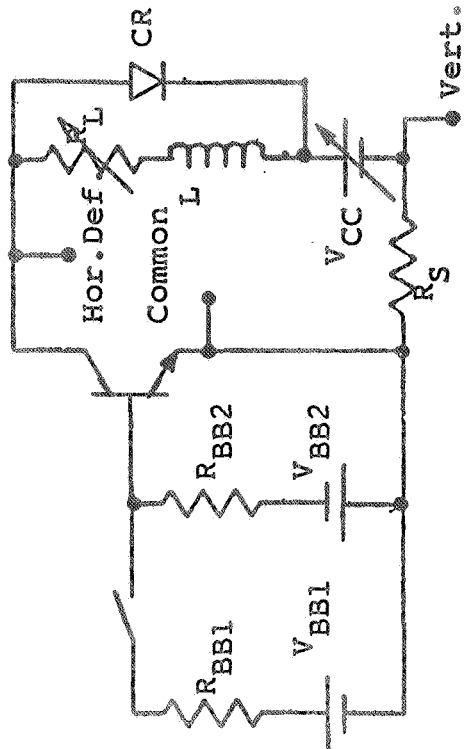


Figure 3



Test Circuit: JS-6-T5.2.1

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

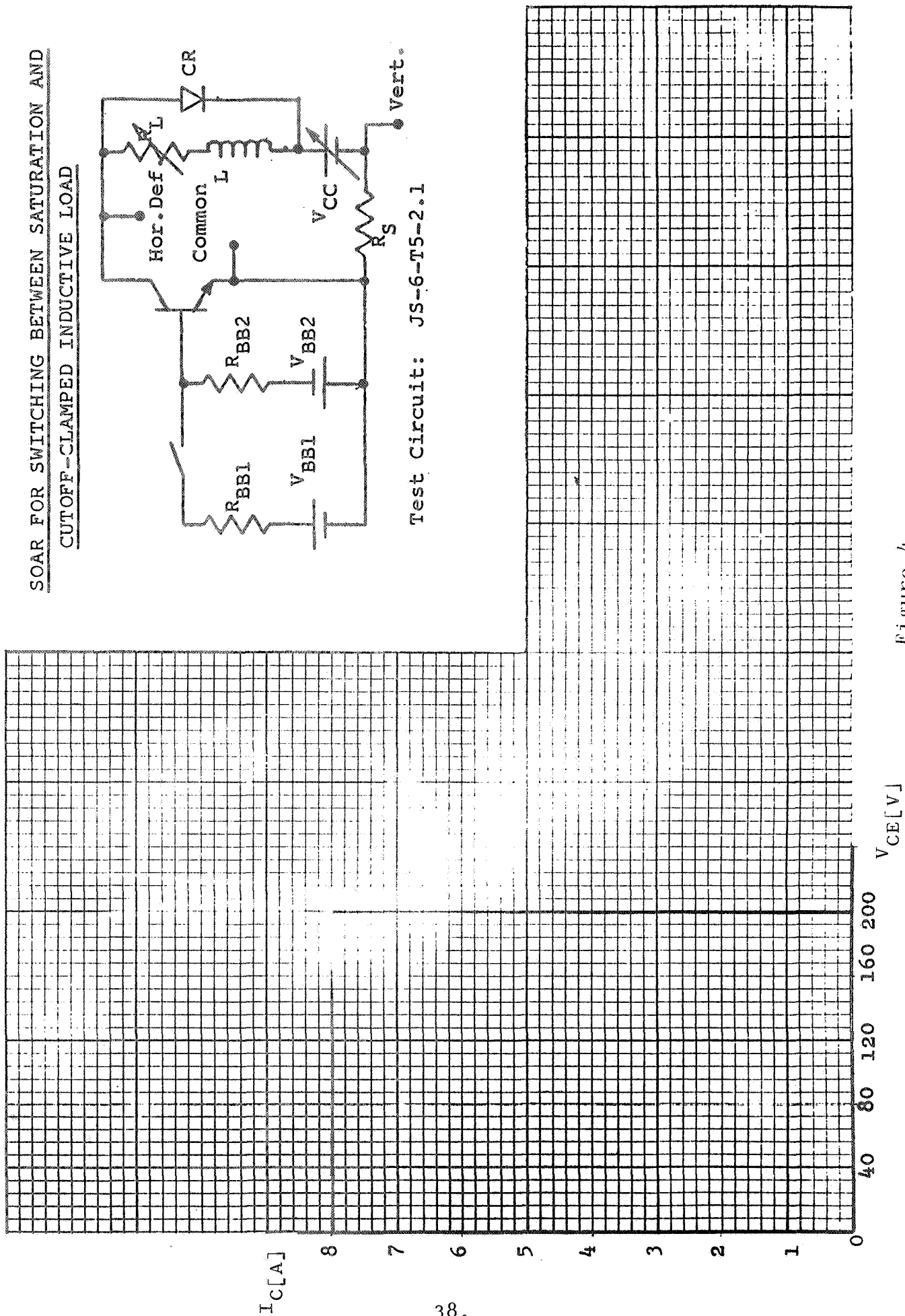
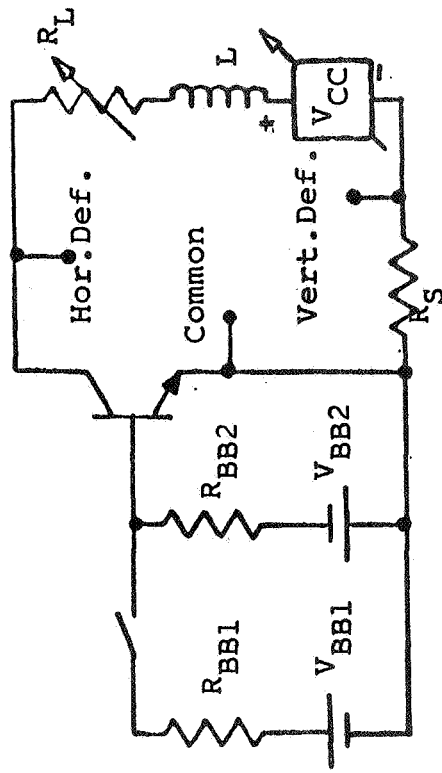


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

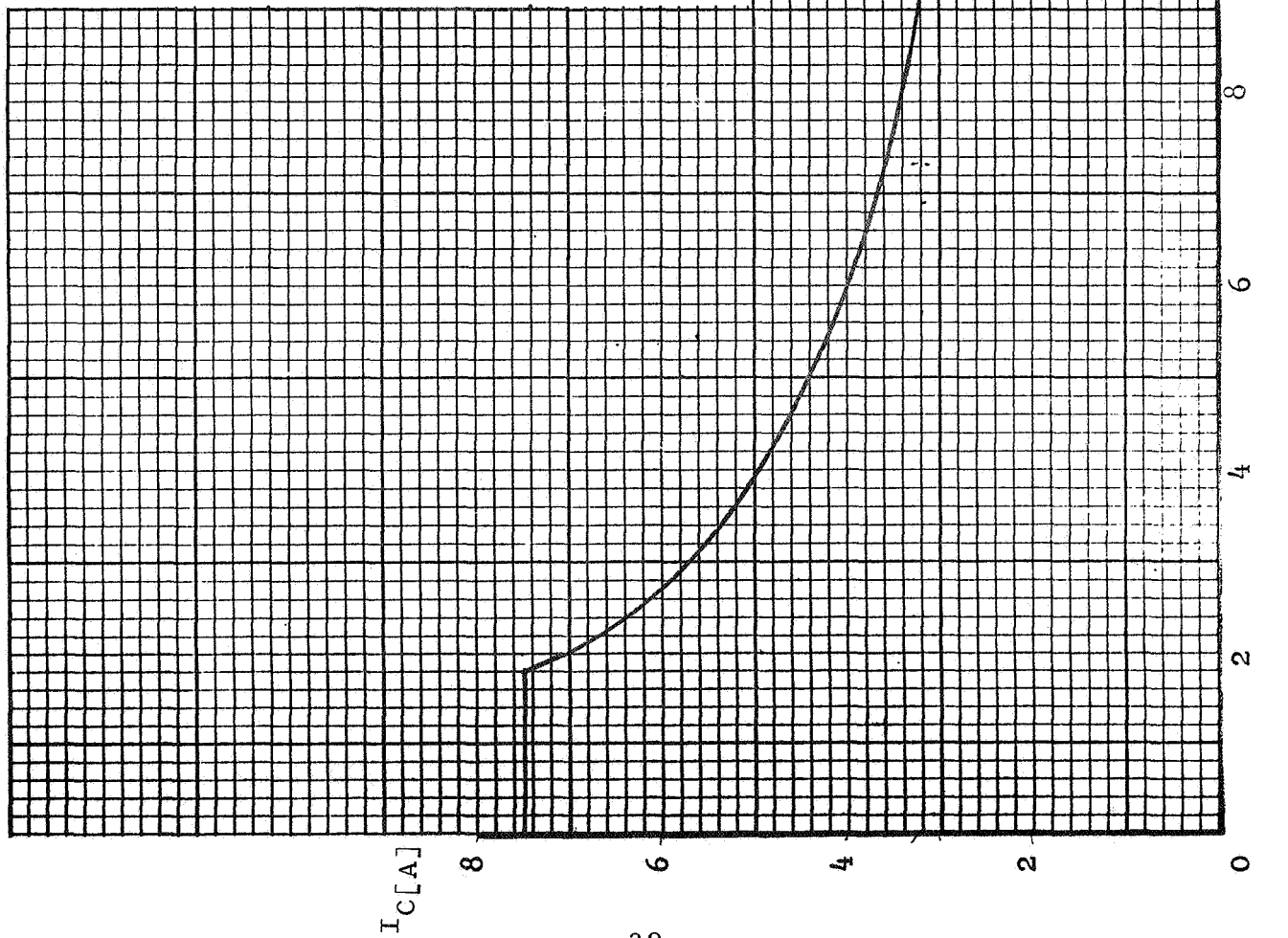


Figure 5

SHORTED CLASS B SOAR

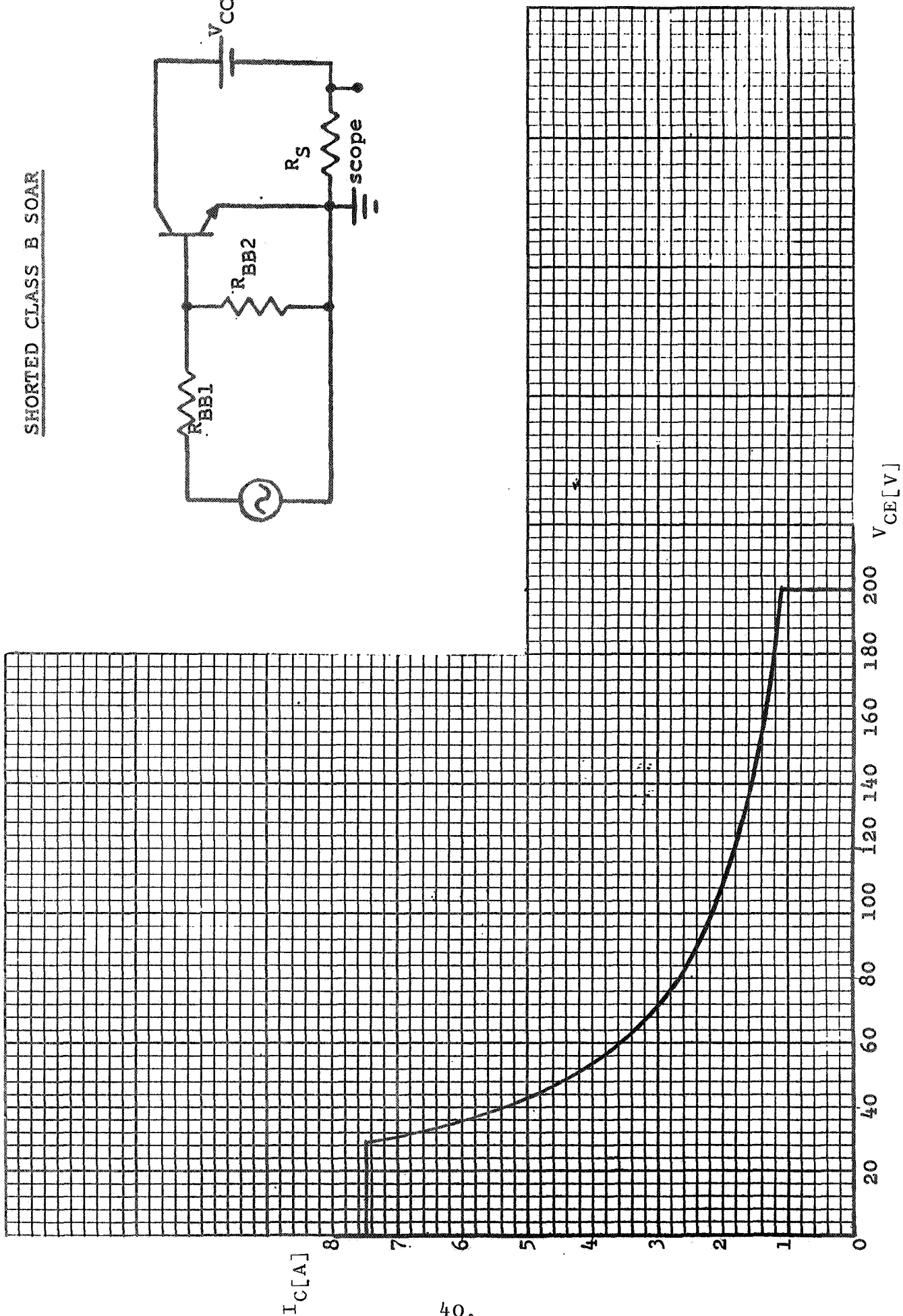
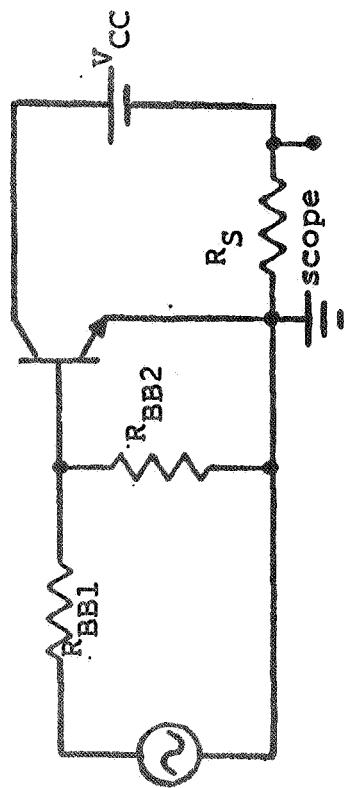


Figure 6

Silicon Power Transistor
< Type 2N1514 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract No. NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type NPN	
1.2.0	Material -- Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline -- TO-36	
2.2.0	Terminal Designation	
	1 -- Base	
	2 -- Emitter	
	3 -- Collector	
	case -- Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.1</u> (JEDEC suggested Standard: "Test Procedures for Verification of Maximum Ratings.")
	$T_{STG(min)} = -65^{\circ}C$	<u>JS-6-T1.2</u>
3.1.2	$T_J(max) = 200^{\circ}C$	<u>JS-6-T2</u>
		$T_C = 100^{\circ}C$
		$V_{CB} = 10V, I_C = 4.3A$
3.1.3	$T(Lead) = 230^{\circ}C$	Distance from case - 0.25 in
		Time - 10s
3.2.0	Voltage	$T_C = 25^{\circ}C$
3.2.1	$V_{CBO} = 100V$	<u>JS-6-T3</u> or MIL-STD-750A Method 3001.1

<u>Item</u>		<u>Test Methods and Test Conditions</u>
3.2.2	$V_{EBO} = 10V$	<u>JS-6-T4</u> or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 70V$	<u>JS-6-T5.1</u> $I_C (V_{CE} = V_{CEX}) = 6A$ $V_{CC} = 100V, R_L = 16.0\Omega$ $L = 1mH^*, CR = 1N1204$ $V_{BB1} = 7.5V, R_{BB1} = 1\Omega$ $V_{BB2} = 8V, R_{BB2} = 5\Omega$ $R_S = 0.1\Omega$ $t_p = 1ms, \text{Duty Cycle} \leq 1\%$ *Miller No. 7871 in series with Miller No. 7825-3
3.3.0	Current	
3.3.1	$I_C = 6A$	<u>JS-6-T6</u> $I_B = 2A, T_C = 25^\circ C$
3.3.2	$I_B = 3A$	<u>JS-6-T8</u> $T_C = 25^\circ C$
3.3.3	$I_E = 8A$	<u>JS-6-T10</u> $I_B = 2A, T_C = 25^\circ C$
3.4.0	Power	
3.4.1	$P_T = 43W$	<u>JS-6-T12</u> $T_C = 100^\circ C$ $V_{CB} = 10V, I_C = 4.3A$ Derating factor - $0.43W/^\circ C$

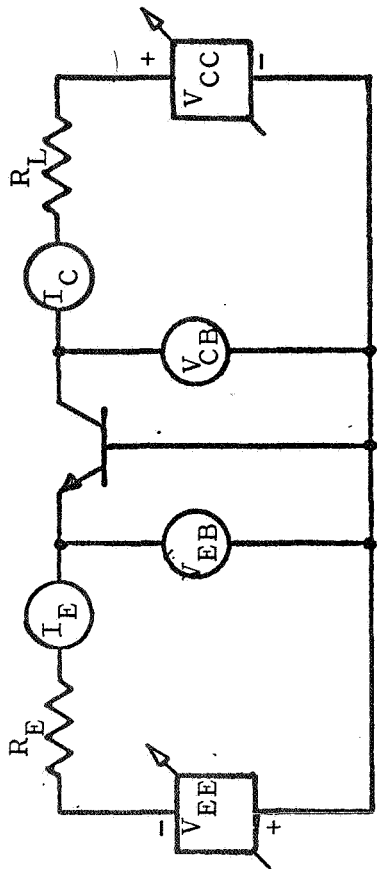
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.4.2 $P_{TM} = I_C V_{CC} = 330W$	<u>JS-6-T13</u> $T_C = 100^{\circ}C$ $V_{CC} = 55V, \quad I_C = 6A$ $V_{BB} = 8V, \quad R_{BB} = 5\Omega$ <u>Input Pulse Characteristics</u> Pulse Width = 10 ms Duty Cycle $\leq 1\%$ $t_r \leq 50\mu s, \quad t_f \leq 50\mu s$ Coll. Current
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> (See Figure 1) Test Point: (See 3.4.1)
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> (See Figure 2) <u>Test Points:</u> $T_C = 100^{\circ}C, \quad V_{BB} = 8V; \quad R_{BB} = 5\Omega$ $t_r \leq 50\mu s, \quad t_f \leq 50\mu s, \quad I_C = 6A$ Duty Cycle $\leq 1\%, \quad R_S = 0.1\Omega$ 1. For $t_p = 20ms; \quad V_{CC} = 30V$ 2. For $t_p = 10ms; \quad V_{CC} = 55V$
3.6.0 SOAR	
	Switching between Saturation and Cutoff
3.6.1 Resistive Load	<u>JS-6-T5-2.1</u> with $L = 0$ and CR disconnected (See Figure 3)

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.1 Resistive Load (Cont'd)	<p><u>Test Point:</u></p> <p>$I_C = 6A$, $V_{CC} = 100V$, $R_{BB1} = 1\Omega$, $R_{BB2} = 5\Omega$, $R_S = 0.1\Omega$, $V_{BB1} = 7.5V$, $V_{BB2} = 8V$, $T_C = 100^\circ C$, (Coll. Current) $t_r \leq 50\mu s$, $t_f \leq 50\mu s$</p>
3.6.2 Clamped Inductive Load	<p><u>JS-6-T5-2.1</u> (See Figure 4)</p> <p><u>Test Point:</u> (See 3.2.3)</p>
3.6.3 Uclamped Inductive Load	<p><u>JS-6-T5-2.1</u> and CR disconnected (See Figure 5)</p> <p><u>Test Points:</u></p> <p>$R_{BB1} = 1\Omega$, $R_{BB2} = 5\Omega$, $R_S = 0.1\Omega$, $V_{BB1} = 7.5V$, $V_{BB2} = 8V$, $T_C = 25^\circ C$, $f = 60Hz$, $d = 10\%$</p> <p>1. $I_C = 6A$, $V_{CC} = 18V$, $R_L = 2\Omega$, $L=10mH^*$ 2. $I_C = 2.5A$, $V_{CC} = 28V$, $R_L = 10\Omega$, $L=40mH$</p> <p>*Stancor - C-2688 **Series Stancor-C-2688</p>
3.7.0 Shorted Class B SOAR	<p>(See Figure 6)</p> <p><u>Test Point:</u></p> <p>$I_C \text{ peak} = 2.6A$, $V_{CC} = 55V$, $R_S = 0.1\Omega$, $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$, $T_C = 100^\circ C$</p>

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.0.0	Electrical Characteristics	$T_C = 25^{\circ}\text{C}$ [unless otherwise noted]
	Maximum limits unless otherwise noted	
	Technique:	
	DC - Continuous Operation	
	C.T. - Curve Tracer	
	P - 300 μs Pulse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEO} = 100\text{mA}$	$V_{CE} = 55\text{V}$ Technique - C.T.
4.1.2	$I_{CBO} = 2\text{mA}$	$V_{CB} = 30\text{V}$, $T_C = 200^{\circ}\text{C}$ Technique - C.T.
4.1.3	$V_{EBF} = 1.5\text{V}$	$V_{CB} = 30\text{V}$, $T_C = 200^{\circ}\text{C}$ Technique - C.T.
4.1.4	$I_{EBO} = 25\mu\text{A}$	$V_{EB} = 10\text{V}$, Technique - C.T.
4.1.5	$V_{(BR)CEO} = 55 \text{ minV}$	$I_C = 100\text{mA}$ Technique - C.T.
4.1.6	$h_{FE} = 25 \text{ min}$ " = 75 max	$V_{CE} = 4\text{V}$, $I_C = 1.5\text{A}$ Technique - C.T.
4.1.7	$h_{FE} = 7 \text{ min}$	$V_{CE} = 8\text{V}$, $I_C = 6\text{A}$ Technique - P
4.1.8	$V_{CE(sat)} = 6 \text{ max V}$	$I_C = 6\text{A}$, $I_B = 2\text{A}$ Technique - C.T.
4.1.9	$V_{BE} = 7.8 \text{ max V}$	$I_C = 6\text{A}$, $V_{CE} = 8\text{V}$ Technique - P

<u>Item</u>		<u>Test Methods and Test Conditions</u>
5.0.0	Thermal Characteristics	
5.1.0	$T_{J \text{ min}} = 5\text{ms}$	$I_C = 2\text{A}$, $V_{CE} = 10\text{V}$, $T_C = 25^\circ\text{C}$ MIL-STD-750 Method 3146.1
5.2.0	$\theta_{JC \text{ max}} = 2.33^\circ\text{C/W}$	$I_C = 2\text{A}$, $V_{CE} = 10\text{V}$, $T_C = 25^\circ\text{C}$ MIL-STD-750 Method 3136
6.0.0	$f_{hfe} = 10\text{KHz}(\text{min})$ $40\text{KHz}(\text{max})$	$I_C = 100\text{mA}$, $V_{CE} = 6\text{C}$ MIL-STD-750 Method

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

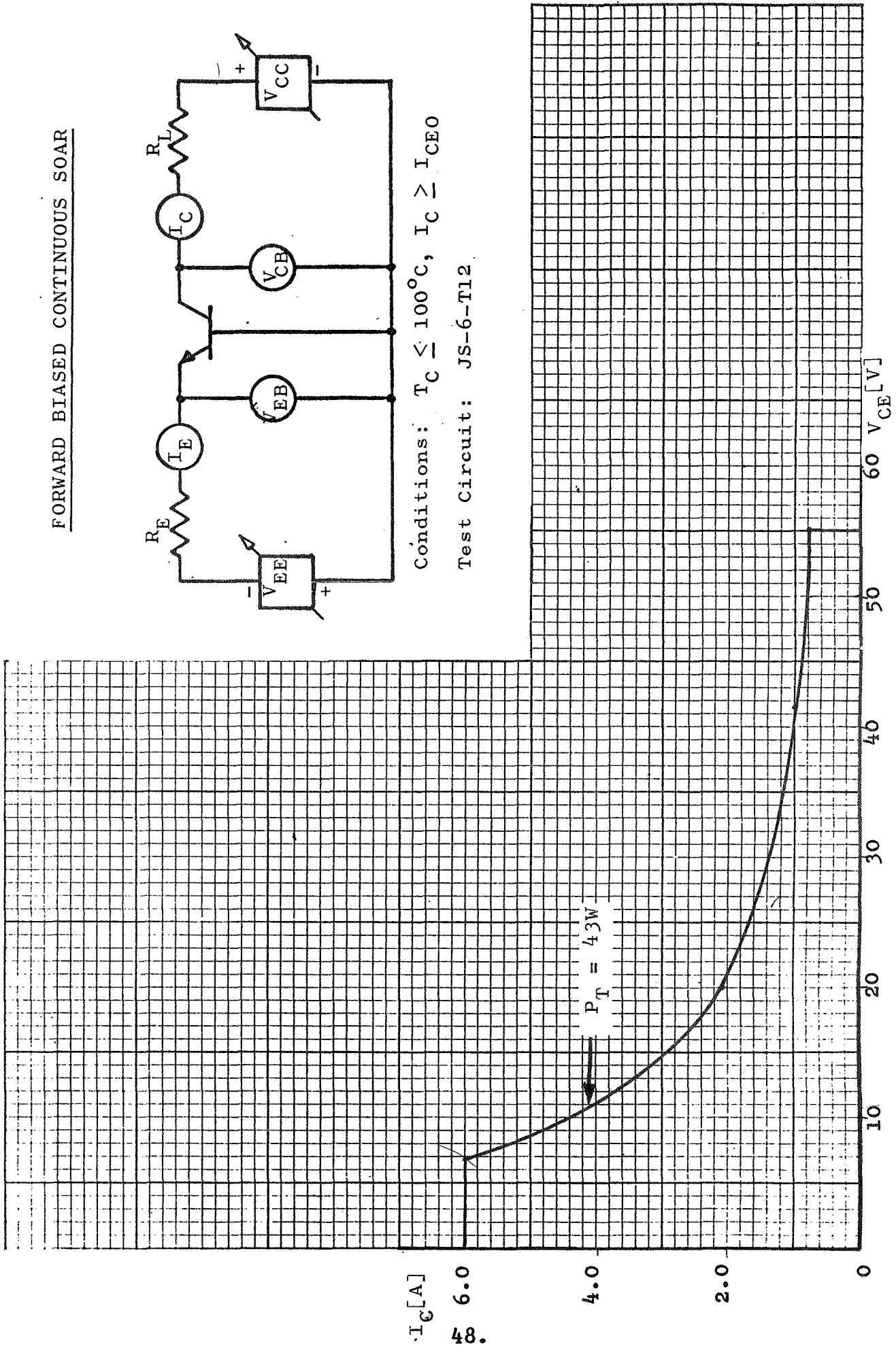


Figure 1

PULSED FORWARD BIASED SOAR

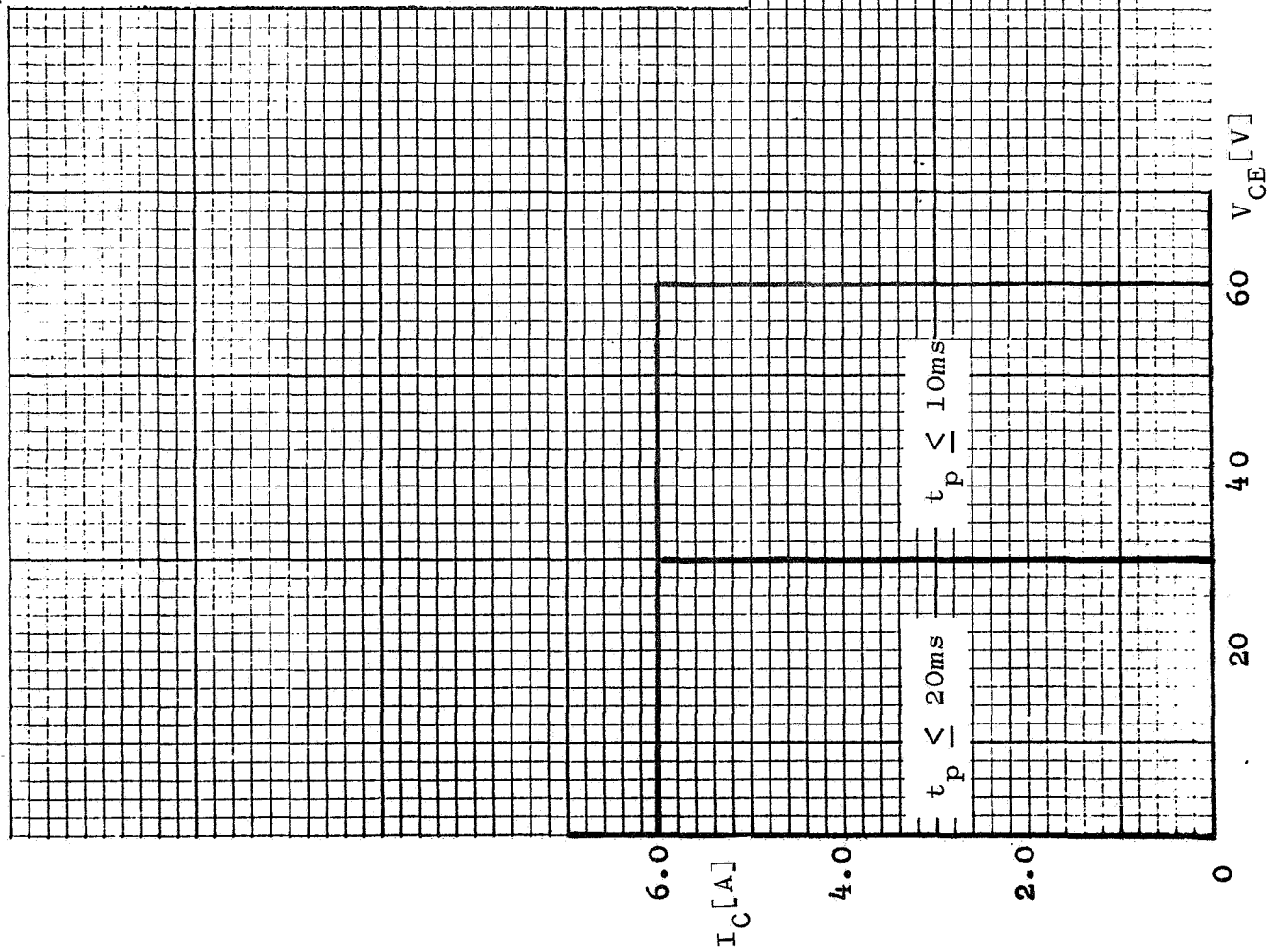
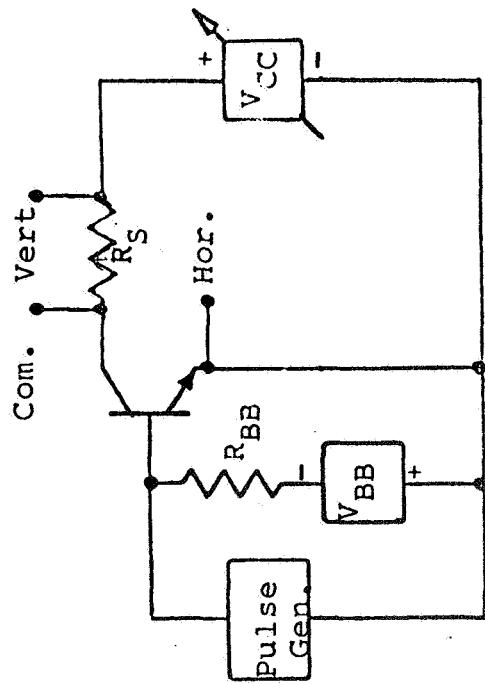


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

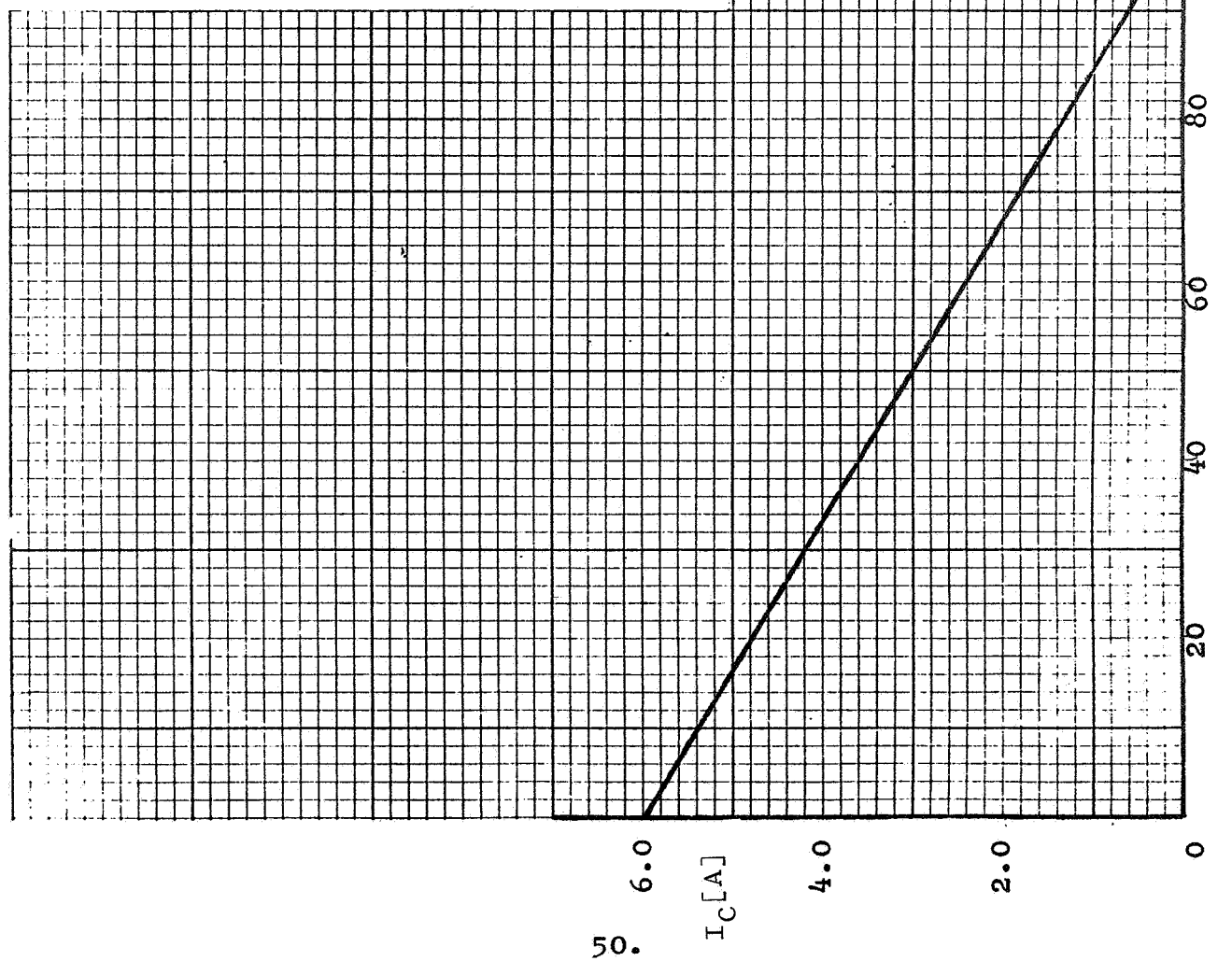
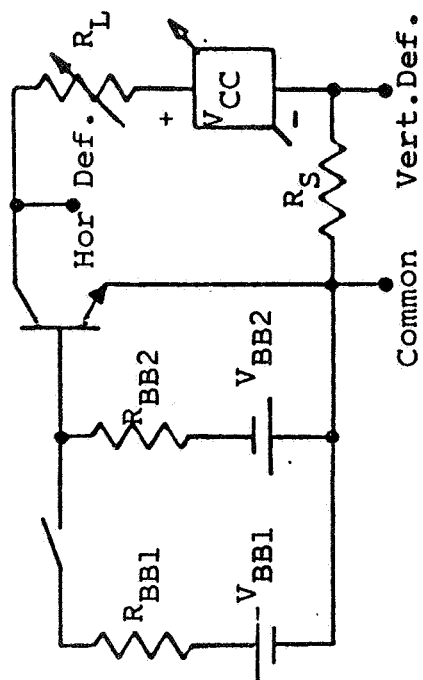
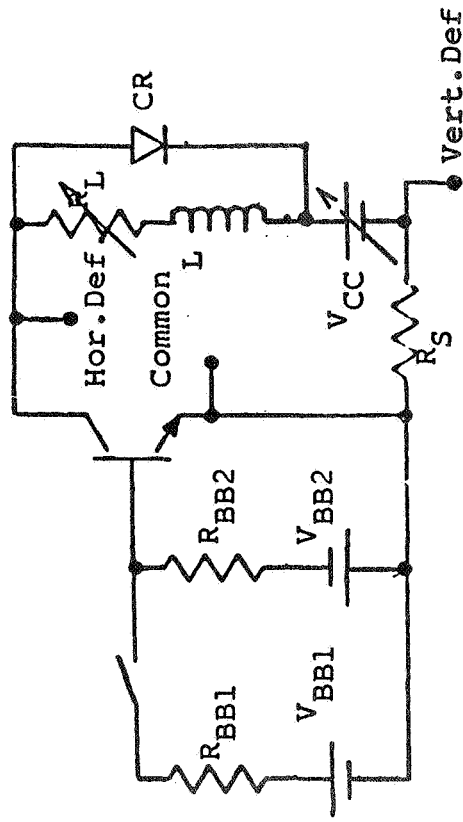


Figure 3



Test Circuit: JS-6-T5.2.1

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

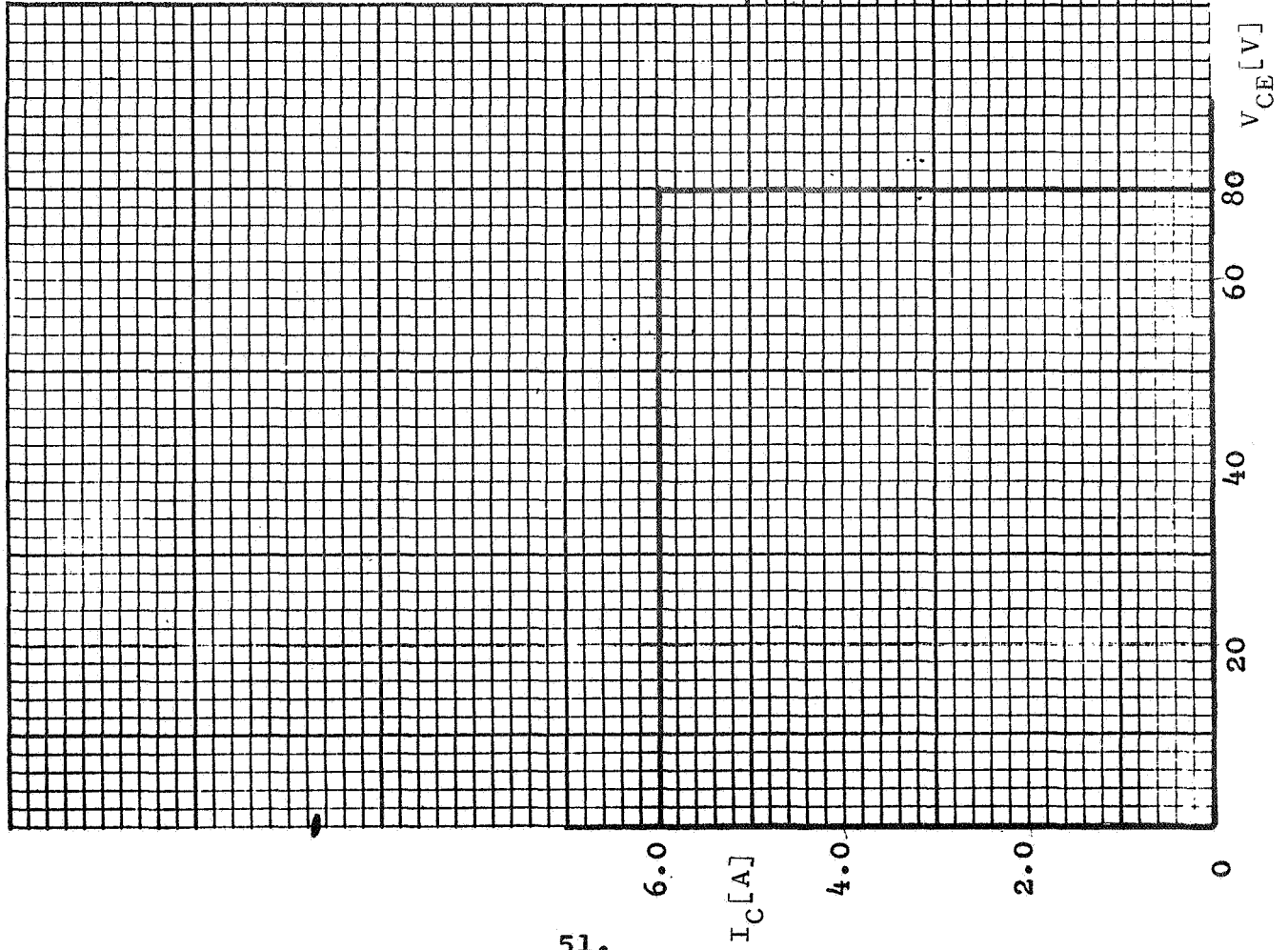
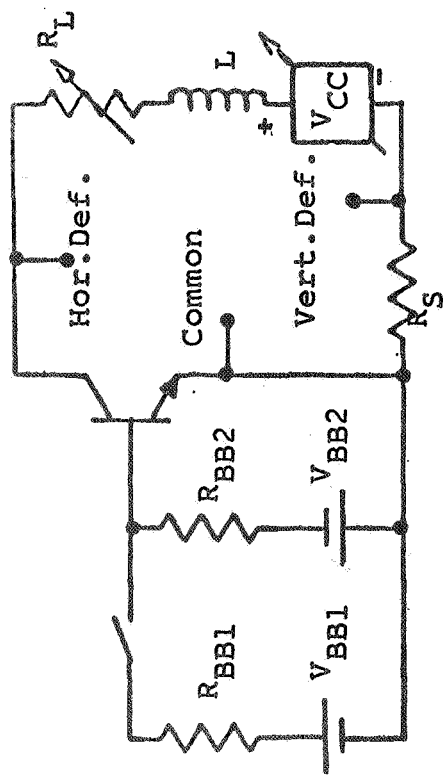


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

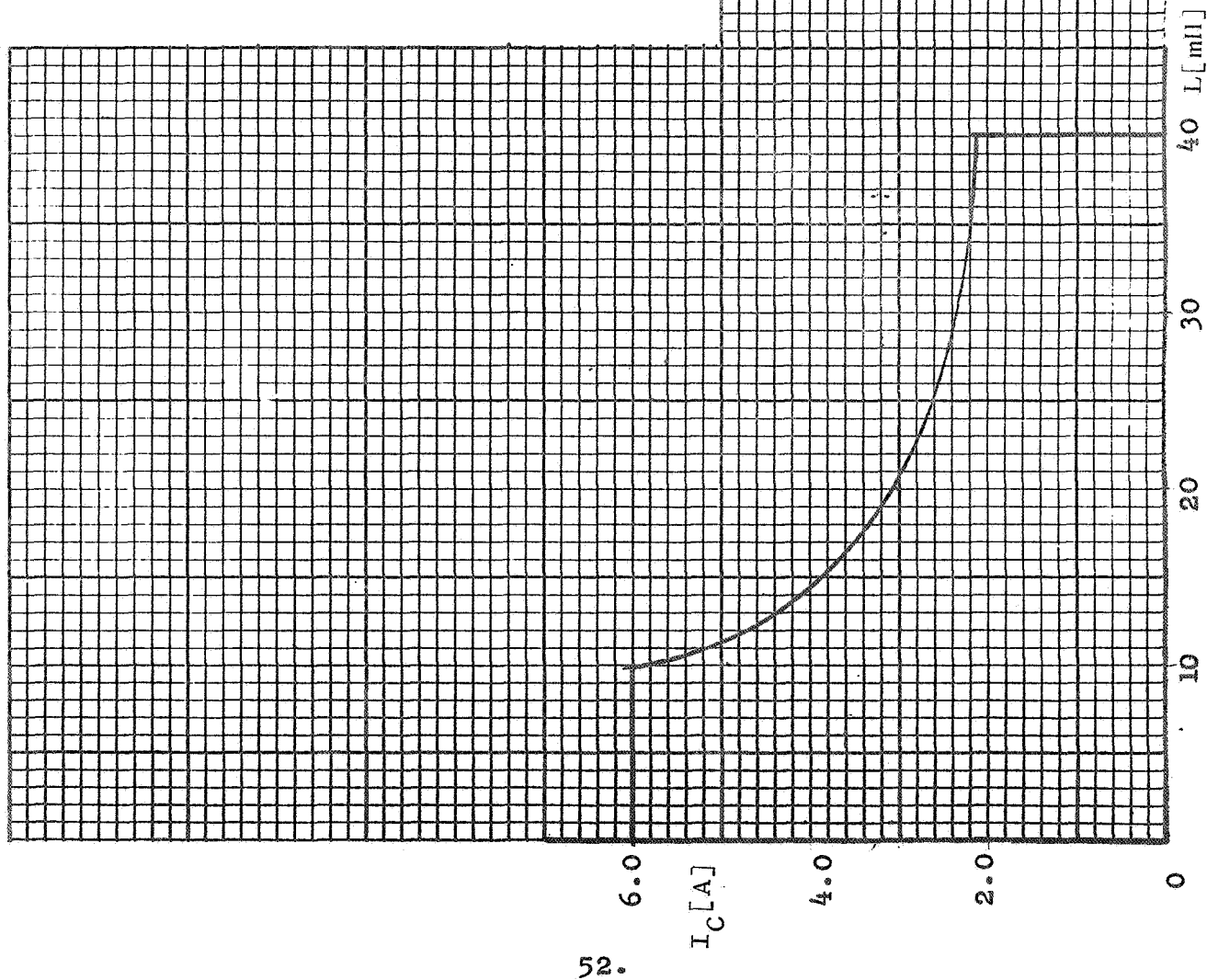


Figure 5

SHORTED CLASS B SOAR

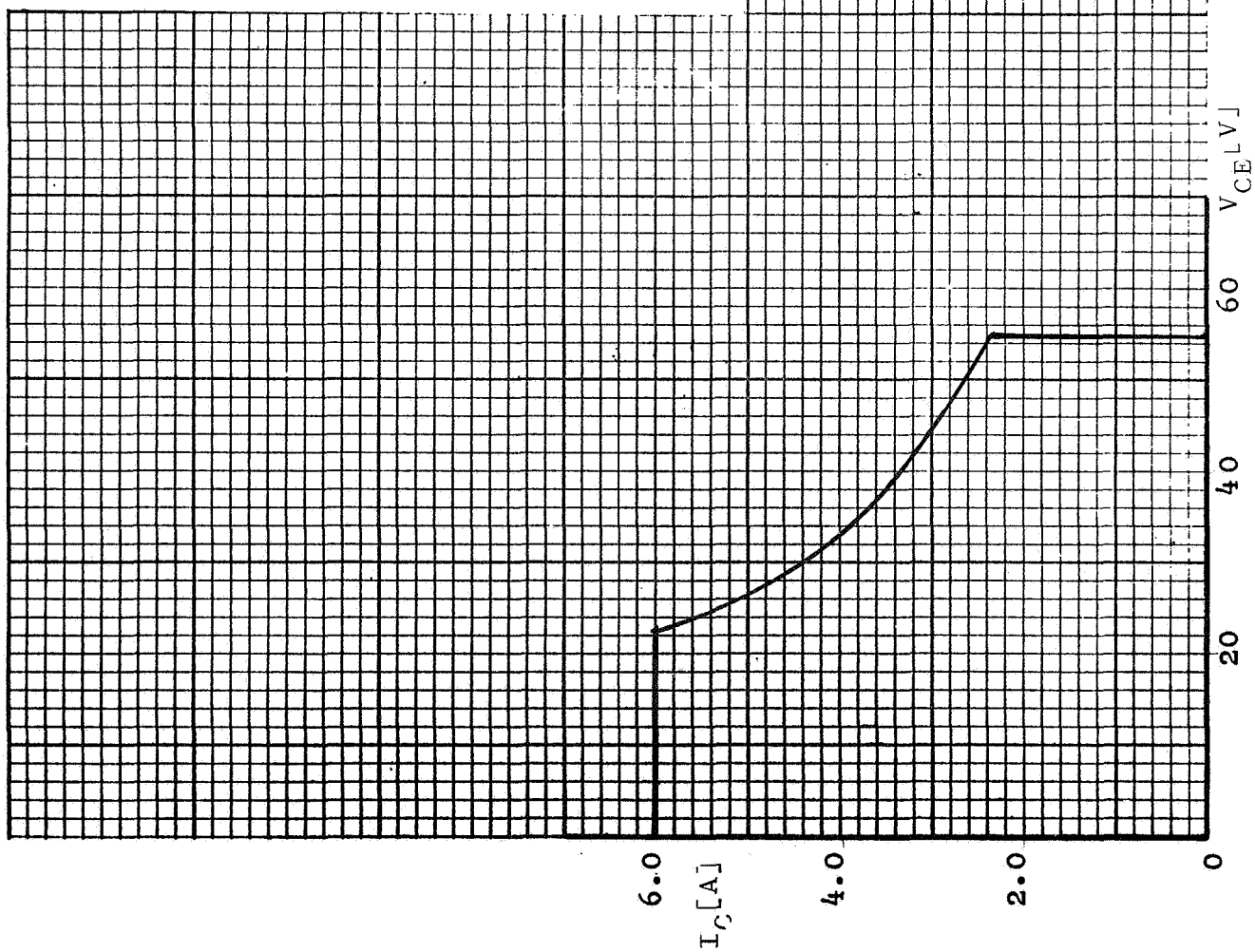
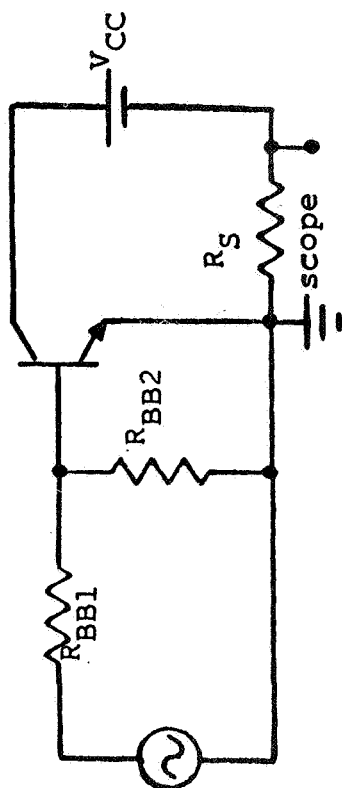


Figure 6

SILICON POWER TRANSISTOR

< Type 2N2102 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturers D & J --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline - T0-5	
2.2.0	Terminal Designation	
	1 - Base	
	2 - Emitter	
	3 - Collector	
	Case - Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -65^{\circ}C$ $T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.1</u> [JEDEC Suggested Standard: "Test Procedure for Verification of Maximum Ratings" JEDEC Publication No. 65]
3.1.2	$T_{J(max)} = 200^{\circ}C$	<u>JS-6-T2</u> $T_C = 100^{\circ}C$, $P_T = 2.86W$, $I_C = 55mA$
3.1.3	$T(Lead) = 300^{\circ}C$	Distance from case $1/16" \pm 1/32"$ Time = 10 sec (max)
3.2.0	Voltage	
3.2.1	$V_{(BR)CBO} = 120V$	<u>JS-6-T3</u>
3.2.2	$V_{(BR)EBO} = 7V$	<u>JS-6-T4</u>

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.2.3 $V_{(BR)CEO} = 65V$	<u>JS-6-T5.1</u> CR Disconnected $I_C = 0.1A$, $R_{BB1} = 25\Omega$, $V_{BB1} = 5V$, $R_{BB2} = \infty\Omega$, $d = 50\%$, $f = 60Hz$, $L^* = 5.0mH$, $R_L = 0$, $R_S = 1.0\Omega$ Adjust V_{CC} for specified I_C *Chicago Standard Transformer Corp. C-2689
3.3.0 Current	
3.3.1 $I_C = 1.0A$	<u>JS-6-T6</u> $I_B = 0.3A$, $T_C = 25^{\circ}C$
3.3.2 $I_B = 0.3A$	<u>JS-6-T8</u> $T_C = 25^{\circ}C$
3.3.3 $I_E = 1.3A$	<u>JS-6-T10</u> $I_B = 0.3A$, $T_C = 25^{\circ}C$
3.4.0 Power	
3.4.1 $P_T = 2.86W$	<u>JS-6-T12</u> <u>Test Point:</u> See 3.1.2
3.4.2 $P_{TM} = I_C V_{CC} = 80W$	<u>JS-6-T13</u> $T_C = 25^{\circ}C$, $V_{CC} = 80$, $V_{BB} = 5V$, $R_{BB} = 25$, $I_C = 1.0A$, Pulse Width=100 μs Duty Cycle $\leq 2\%$, $t_r \leq 5\mu s$ $t_f \leq 5\mu s$
3.5.0 Maximum Operating Conditions	

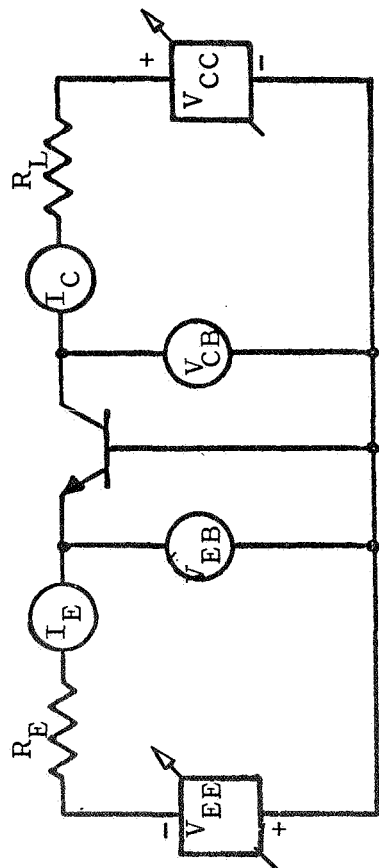
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> <u>Test Points:</u> See 3.1.2
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> <u>Test Points:</u> $T_C = 100^{\circ}\text{C}$, $V_{BB} = 5\text{V}$, $R_{BB} = 20\Omega$, $t_r \leq 5\mu\text{s}$, $t_p \leq 5\mu\text{s}$, $I_C = 1.0\text{A}$, Duty Cycle $\leq 2\%$, $R_S = 1.0\Omega$ 1. $t_p = 1\text{ms}$: $V_{CC} = 35\text{V}$ 2. $t_p = 500\mu\text{s}$: $V_{CC} = 45\text{V}$ 3. $t_p = 100\mu\text{s}$: $V_{CC} = 80\text{V}$
3.6.0 SOAR Switching between Saturation and cutoff	
3.6.1 Resistive Load	<u>JS-6-T5.1</u> with $L = 0$ and CR disconnected <u>Test Points:</u> $R_{BB1} = 20\Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 8.0\text{V}$, $V_{BB2} = 5\text{V}$, $T_C = 100^{\circ}\text{C}$, $t_f \leq 5\mu\text{s}$, $t_r \leq 5\mu\text{s}$, $R_S = 1.0\Omega$, $R_L = 78\Omega$, $V_{CC} = 80\text{V}$, $d = 10\%$
3.6.2 Clamped Inductive Load	<u>JS-6-T5.1</u> <u>Test Point:</u> $I_C \leq 1.0\text{A}$, $V_{CE} = 80\text{V}$, $R_{BB1} = 20\Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 8\text{V}$, $V_{BB2} = 5\text{V}$, $R_L = 8\Omega$, $L^* = 1.0\text{mH}$, *J.W.Miller: 7871 in series with 7825-3

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.3 Unclamped Inductive Load	<u>JS-6-T5.1</u> and CR disconnected <u>Test Points:</u> 1. $V_{BB1} = 8.0V$ $L^* = 1.0mH$ $R_{BB1} = 20\Omega$ $R_L = 66.66\Omega$ $V_{BB2} = 5.0V$ $V_{CC} = 10V$ $R_{BB2} = 100\Omega$ $f = 60Hz$ $R_S = 1.0\Omega$ $d = 10\%$ *J.W. Miller: 7871 in series with 7825-3 2. $V_{BB1} = 8.0V$ $L^* = 50\mu H$ $R_{BB1} = 20\Omega$ $R_L = 7\Omega$ $V_{BB2} = 5V$ $V_{CC} = 10V$ $R_{BB2} = 100\Omega$ $f = 60Hz$ $R_S = 1.0\Omega$ $d = 10\%$ *J.W. Miller: 7825-8
3.7.0 Shorted Class B SOAR	(See Figure 6) <u>Test Points:</u> $I_C \text{ peak} = 0.22A$, $V_{CC} = 32.5V$, $R_S = 1.0\Omega$, $R_{BB1} = 20\Omega$, $R_{BB2} = 100\Omega$ $f = 20Hz$, $T_C = 100^\circ C$
4.0.0 <u>Electrical</u> <u>Characteristics</u>	$T_C = 25^\circ C$ (unless otherwise noted) Maximum limits unless otherwise noted Technique: DC - Continuous Operation C.T. - Curve Tracer P - 300 μs Pulse, 2% Duty Cycle

<u>Item</u>		<u>Test Methods and Test Conditions</u>
4.1.0	Static	
4.1.1	$I_{CBO} = 2.0nA$	$V_{CB} = 60V$, Technique MIL-STD-3036-10
4.1.2	$I_{CBO} = 2.0\mu A$	$V_{CB} = 60V$, $T_C = 150^{\circ}C$, Technique MIL-STD-3036-D
4.1.3	$I_{EBO} = 2.0nA$	$V_{BE} = -5V$, Technique MIL-STD-3061-D
4.1.4	$V_{(BR)CEO} = 65V$ min	<u>JS-6-T5.1</u> (See 3.2.3)
4.1.5	$V_{(BR)CER} = 80V$ min	<u>JS-6-T5.1</u> (See 3.2.3 except $R_{BB2} = 10\Omega$, $V_{BB2} = 0$)
4.1.6	$V_{(BR)CBO} = 120V$ min	$I_C = 1mA$ Technique C.T.
4.1.7	$V_{(BR)EBO} = 7V$ min	$I_E = 1mA$ Technique C.T.
4.1.8	$h_{FE} = 10$ min	$I_C = 1A$, $V_{CE} = 10V$, Technique - P
4.1.9	$h_{FE} = 25$ min	$I_C = 0.5A$, $V_{CE} = 10V$ Technique P
4.1.10	$h_{FE} = 40$ min 120 max	$I_C = 150mA$, $V_{CE} = 10V$ Technique P
4.1.11	$h_{FE} = 10$ min	$I_C = 10mA$, $V_{CE} = 10V$ Technique C.T.
4.1.12	$h_{FE} = 20$ min	$I_C = 0.1mA$, $V_{CE} = 10V$ Technique C.T.
4.1.13	$h_{FE} = 35$ max	$I_C = 10mA$, $V_{CE} = 10V$, $T_C = 55^{\circ}C$ Technique C.T.
4.1.14	$V_{CE(S)} = 2.0V$ max	$I_C = 1.0A$, $I_B = 0.2A$ Technique C.T.
4.1.15	$V_{CE(S)} = 0.5V$ max	$I_C = 150mA$, $I_B = 15mA$ Technique C.T.
4.1.16	$V_{BE(S)} = 2.5V$ max	$I_C = 1.0A$, $I_B = 0.2A$ Technique C.T.
4.1.17	$V_{BE(S)} = 1.1V$ max	$I_C = 150mA$, $I_B = 15mA$ Technique C.T.
4.1.18	$I_{CEO} = 1.0\mu A$ max	$V_{CEO} = 55V$ Technique D.C.
4.1.19	$V_{BEF} = 1.5V$ max	$V_{CB} = 120V$ Technique C.T.
4.2.0	Dynamic	
4.2.1	$t_d + t_r + t_f = 30ns$	Circuit specified with registered spec.

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.2.2	$h_{fe} = 30 \text{ min}, 100 \text{ max}$	$I_C = 1.0\text{mA}, V_{CE} = 5\text{V}, f = 1.0\text{KHz}$
4.2.3	$h_{fe} = 35 \text{ min}, 150 \text{ max}$	$I_C = 5.0\text{mA}, V_{CE} = 10\text{V}, f = 1.0\text{KHz}$
4.2.4	$h_{fe} = 3 \text{ min}, 10 \text{ max}$	$I_C = 50\text{mA}, V_{CE} = 10\text{V}, f = 20\text{MHz}$
4.2.5	NF = 6db	$I_C = 0.3\text{mA}, V_{CE} = 10\text{V}, f = 1\text{KHz}$ R = 1K Ω circuit bandwidth 1Hz
4.2.6	$C_{obo} = 15\text{pf}$	$V_{CB} = 10\text{V}$
4.2.7	$C_{ibo} = 80\text{pF}$	$V_{BE} = 0.5\text{V}$
4.2.8	$h_{ob} = 0.1 \mu\text{mhos min}$	$I_C = 1.0\text{mA}, V_{CE} = 5\text{V}, f = 1\text{KHz}$
4.2.9	$h_{ob} = 0.1 \mu\text{mhos min}$ $1.0 \mu\text{mhos max}$	$I_C = 5.0\text{mA}, V_{CE} = 10\text{V}, f = 1\text{KHz}$
4.2.10	$h_{ib} = 24\Omega \text{ min}, 34\Omega \text{ max}$	$I_C = 1.0\text{mA}, V_{CE} = 5\text{V}, f = 1\text{KHz}$
4.2.11	$h_{ib} = 4\Omega \text{ min}, 8\Omega \text{ max}$	$I_C = 5.0\text{mA}, V_{CE} = 10\text{V}, f = 1\text{KHz}$
4.2.12	$h_{rb} = 3 \times 10^{-4}$	$I_C = 1.0\text{mA}, V_{CE} = 5.0\text{V}, f = 1\text{KHz}$
4.2.13	$h_{rb} = 3 \times 10^{-4}$	$I_C = 5.0\text{mA}, V_{CE} = 10\text{V}, f = 1\text{KHz}$
5.0.0	Thermal Characteristics	
5.1.0	$\tau_J = 75\text{ms min}$	
5.2.0	$\theta_{JC} = 35^\circ\text{C/W max}$	
5.2.1	$\theta_{JA} = 175^\circ\text{C/W max}$	

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

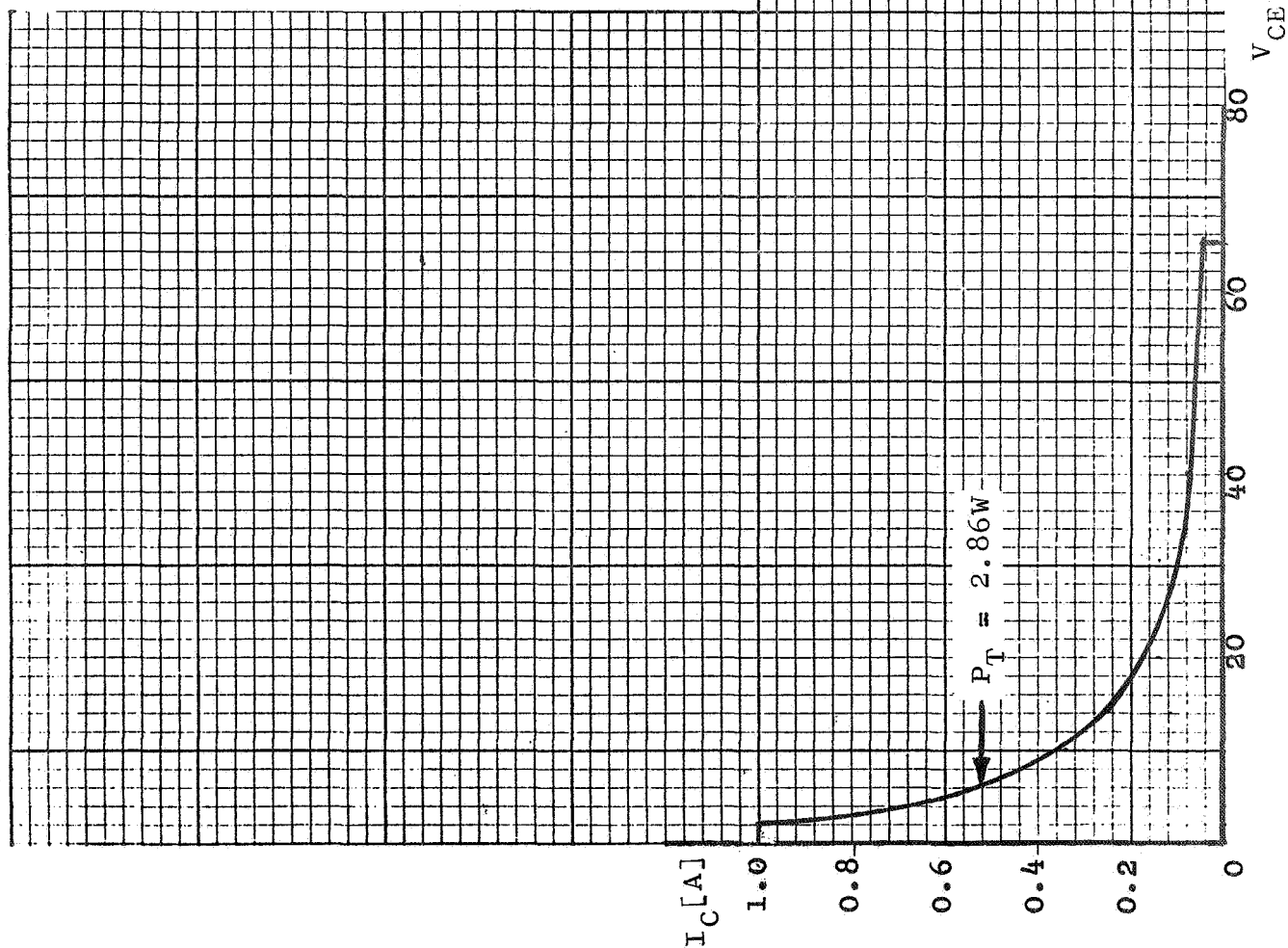
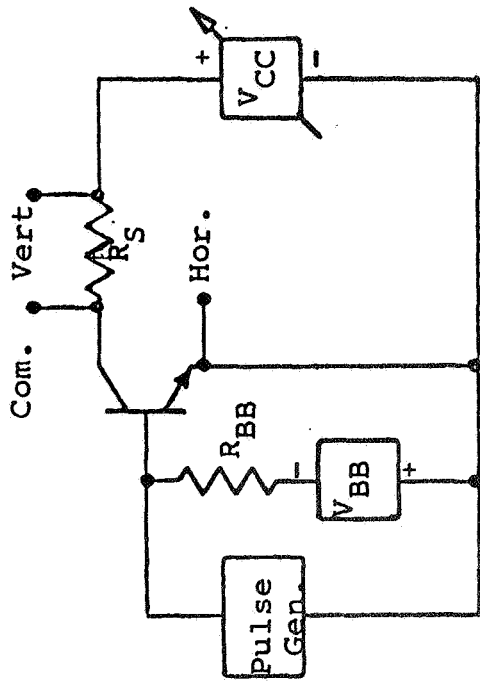


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

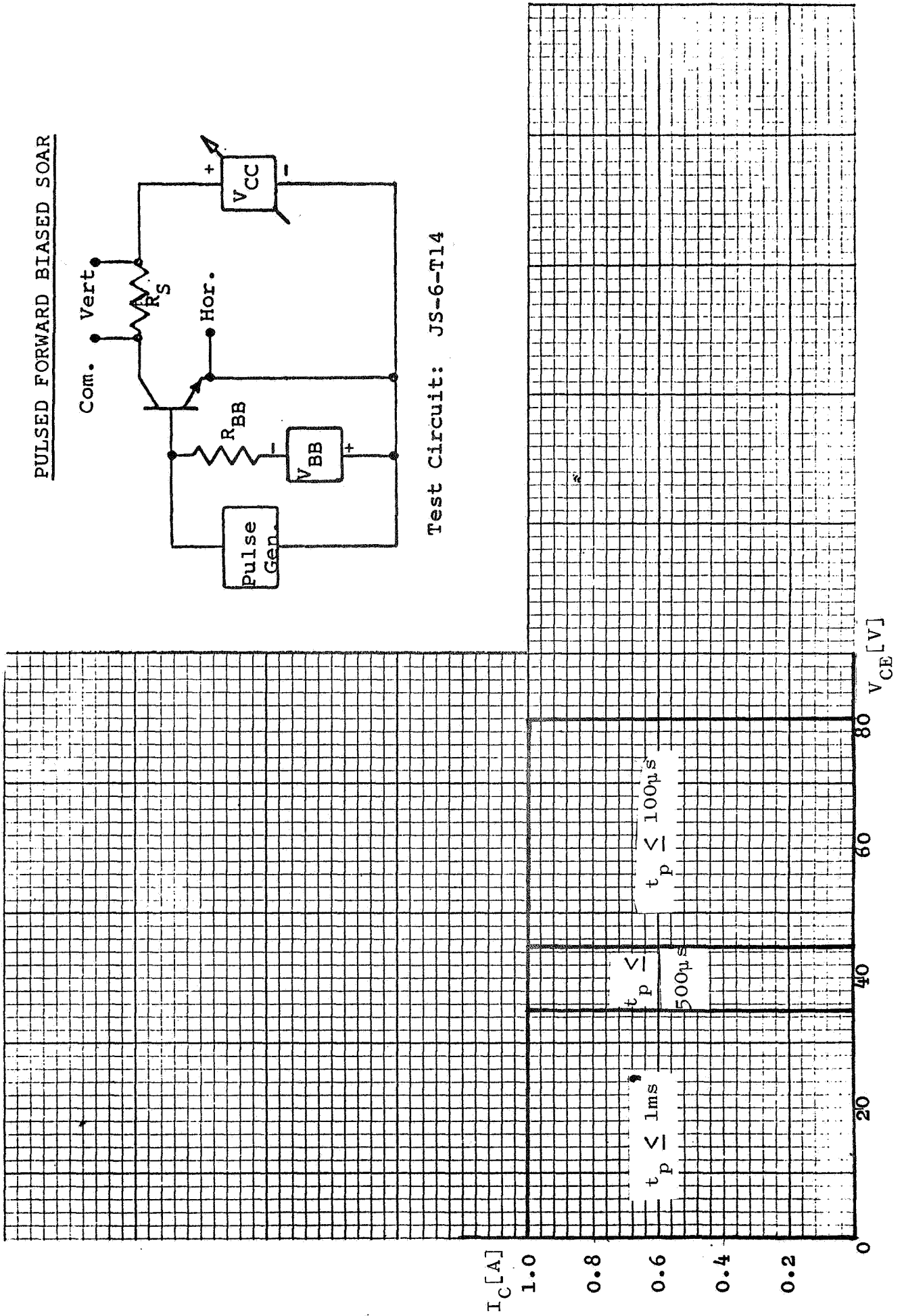


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

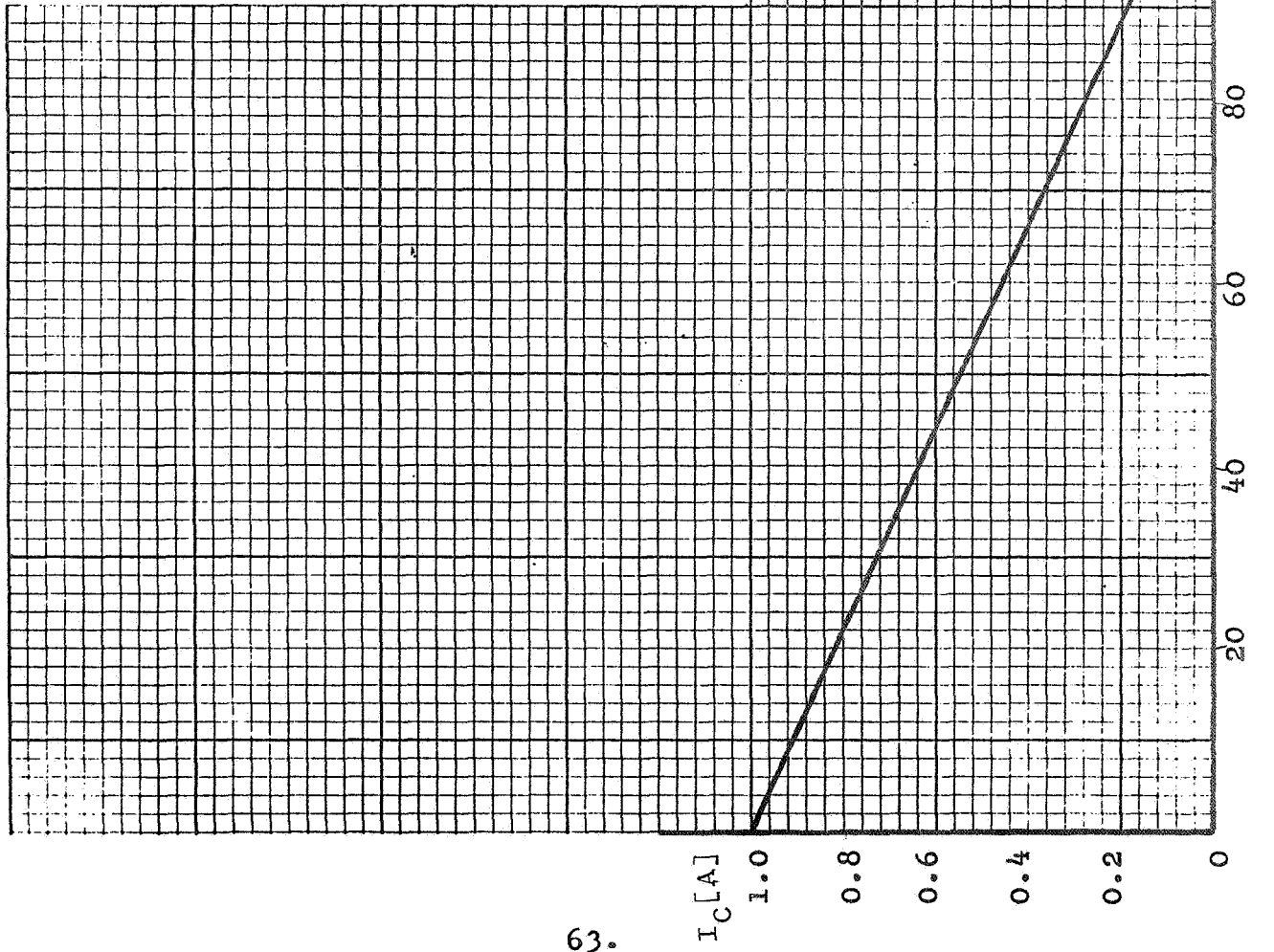
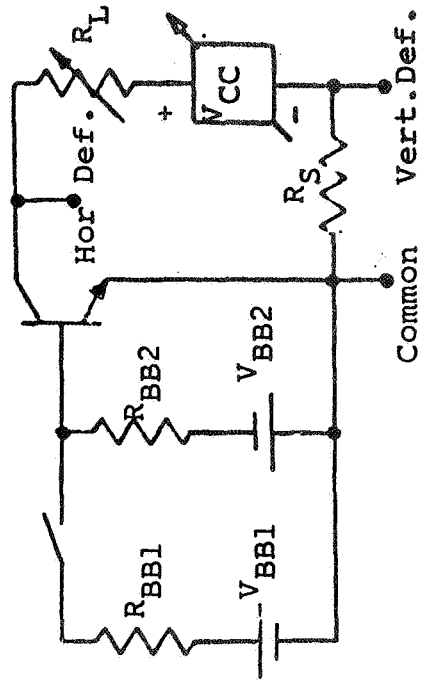
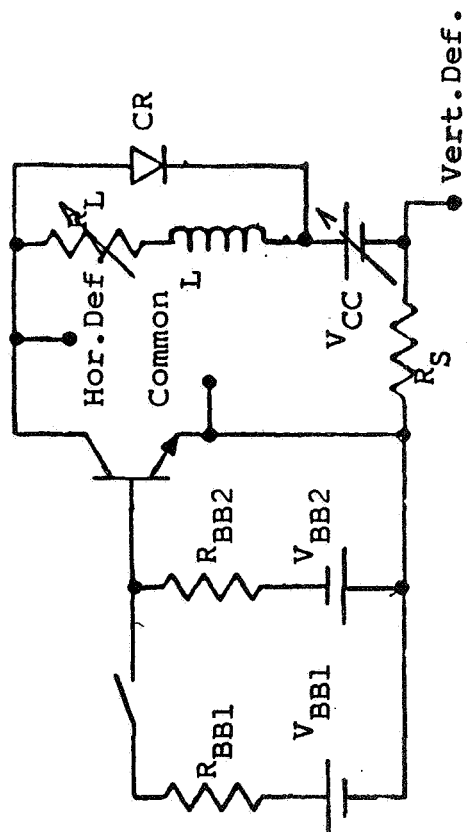


Figure 3



Test Circuit: JS-6-T5.2.1

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

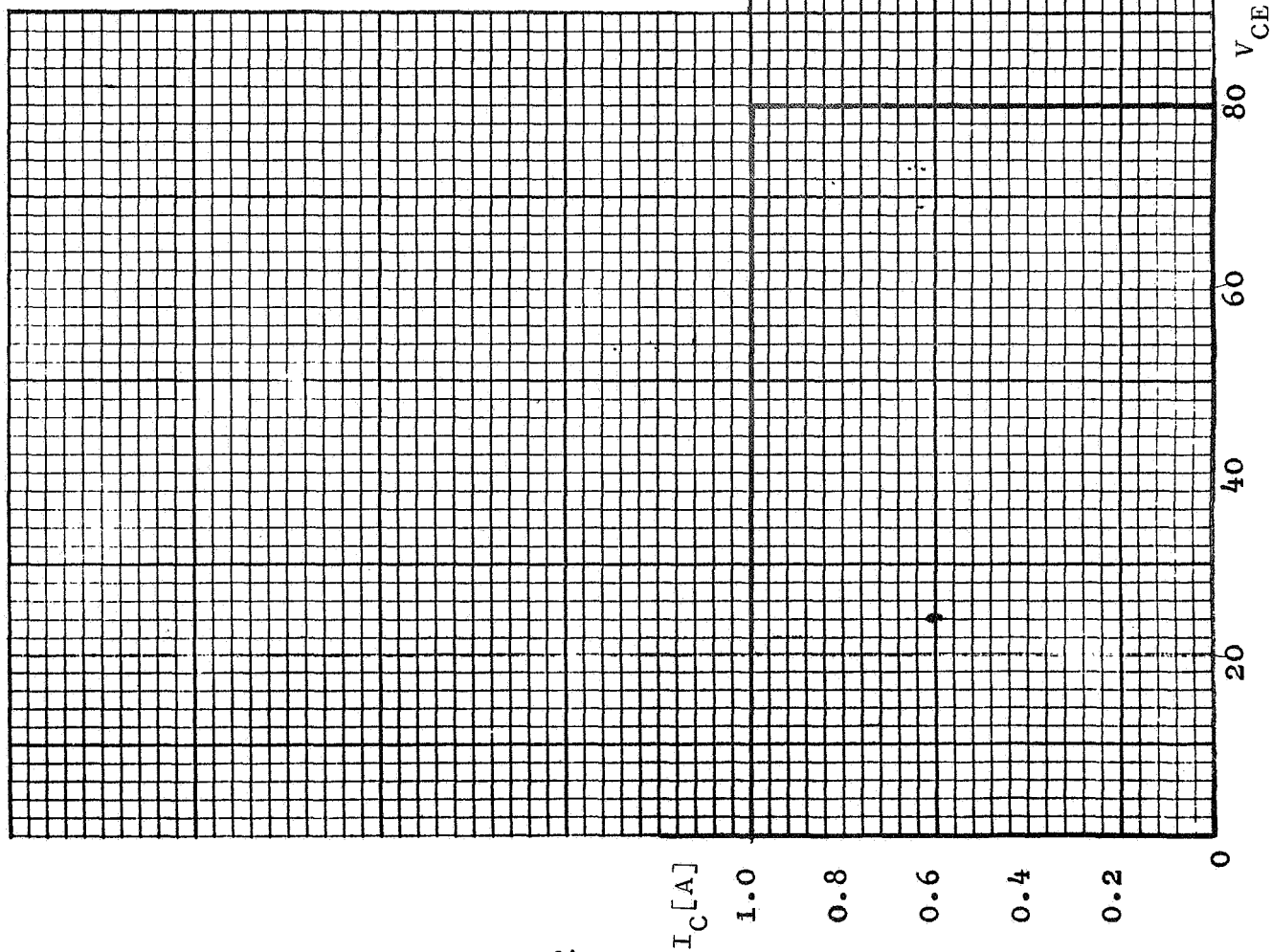
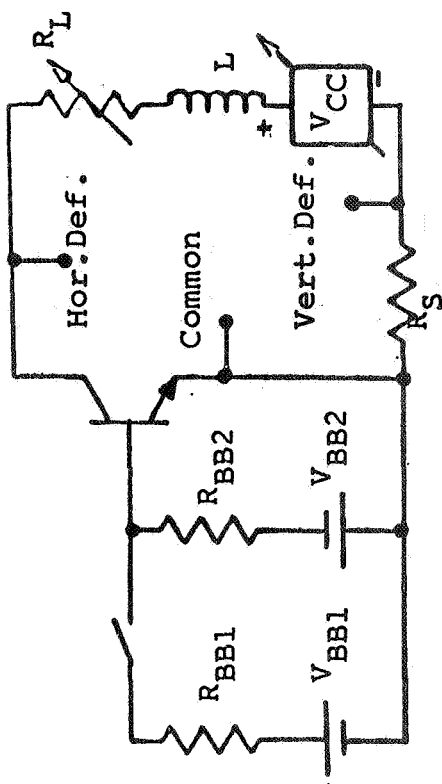


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

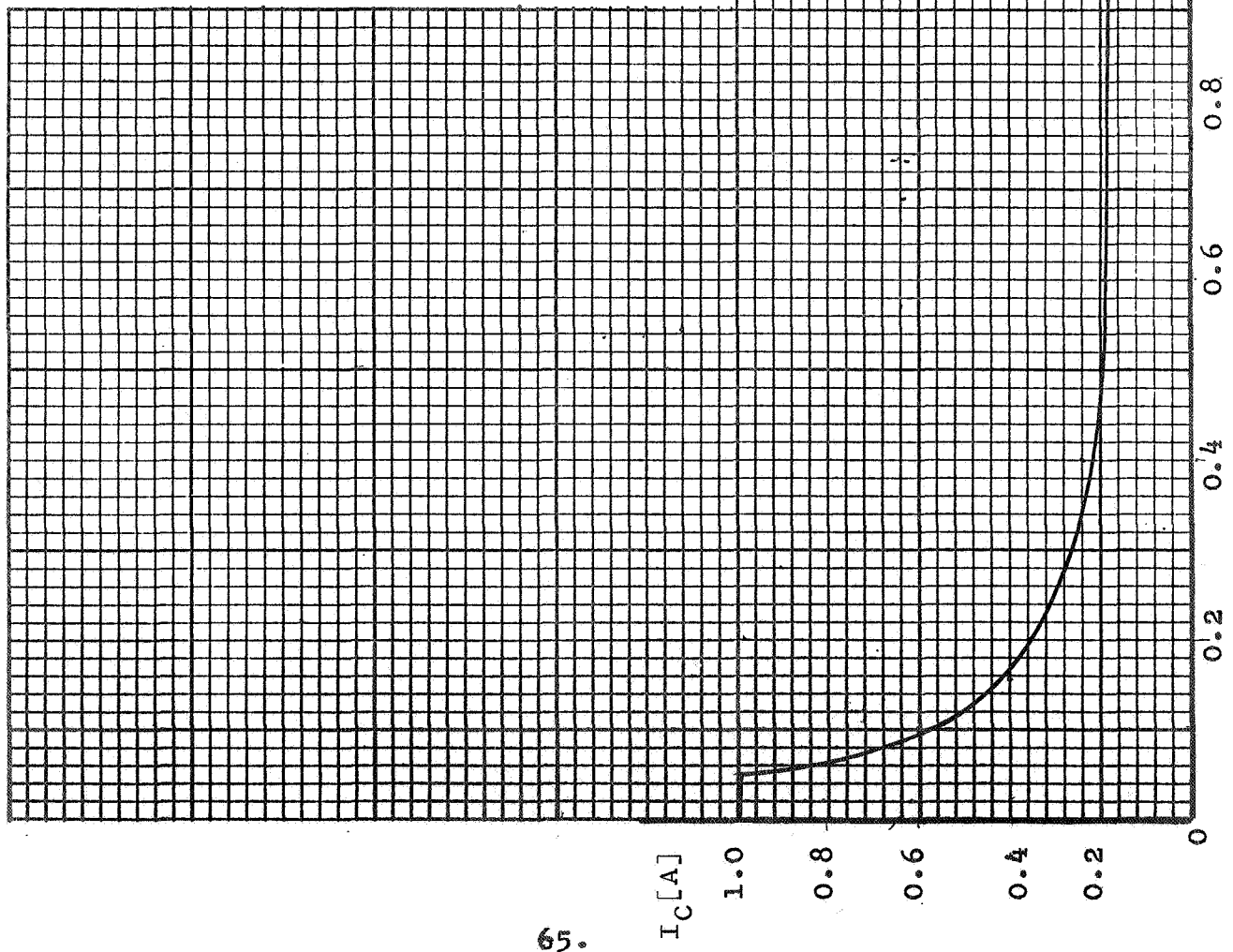


Figure 5

SHORTED CLASS B SOAR

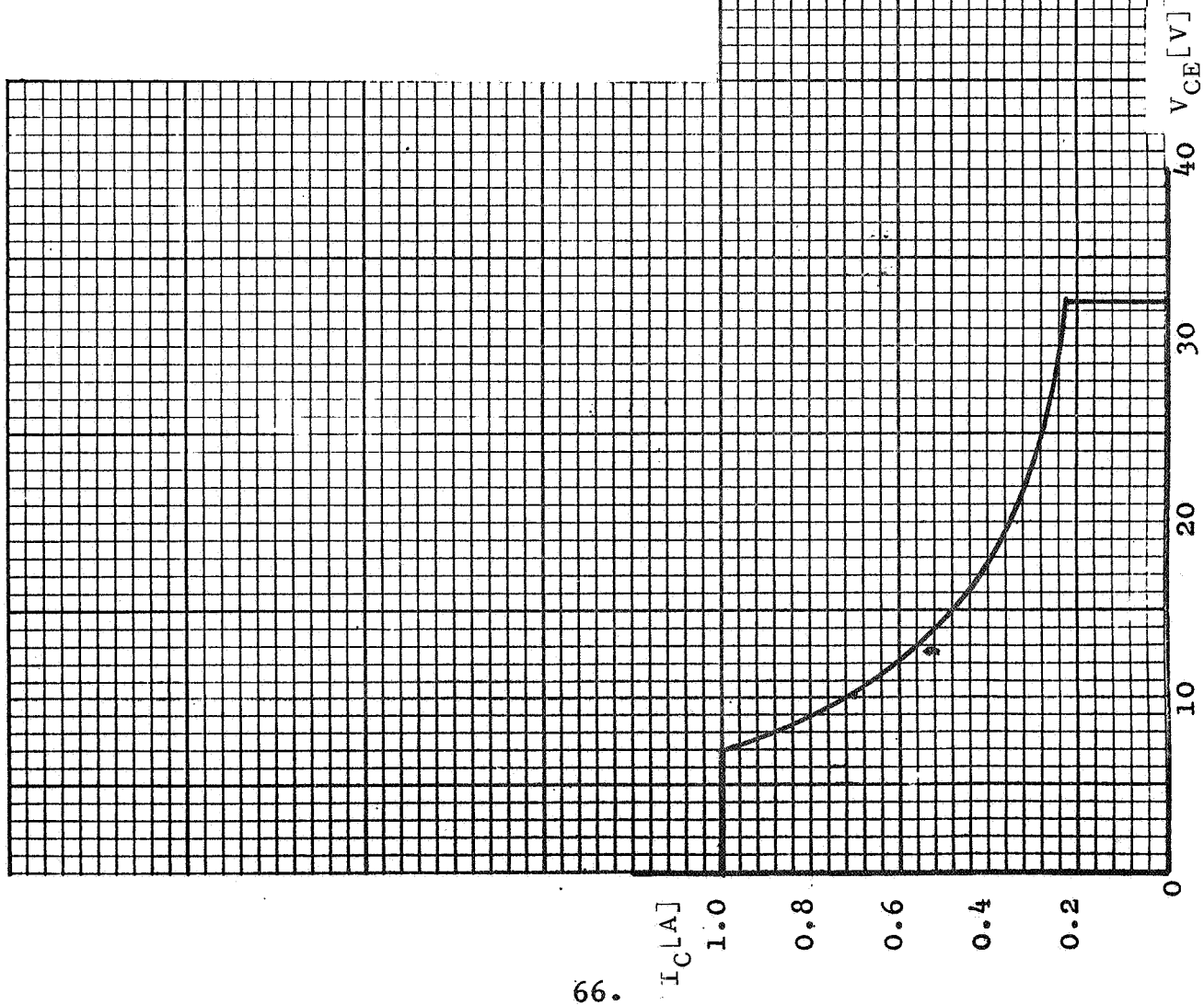
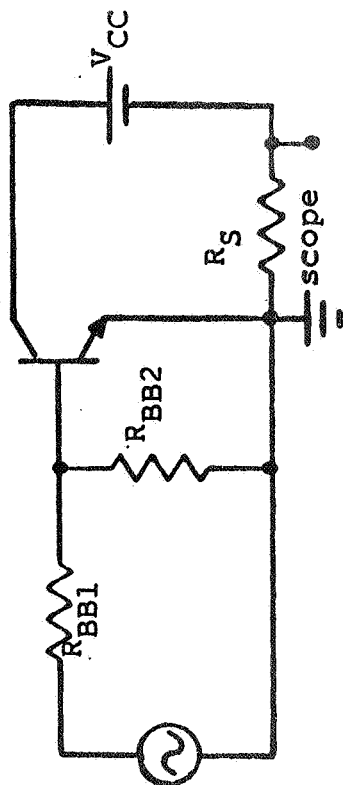


Figure 6

SILICON POWER TRANSISTOR

< S2N2034A >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline - T05	
2.2.0	Terminal Designation	
	1. -- Emitter	
	2. -- Base	
	3. -- Collector	
	case -- Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.2</u> [JEDEC Publication No.65
	$T_{STG(min)} = -65^{\circ}C$	<u>JS-6-T1.1</u> "Test Procedures for
		Verification of Maximum
		Ratings."]
3.1.2	$T_J(max) = 200^{\circ}C$	<u>JS-6-T2</u>
		$T_C = 100^{\circ}C$
		$V_{CB} = 60V, I_C = 83mA$
3.1.3	$T (Lead) = 230^{\circ}C$	Distance from case - 1/16 in.
		Time = 3.0s
3.2.0	Voltage	$T_C = 25^{\circ}C$
3.2.1	$V_{CBO} = 80V$	<u>JS-6-T3</u> or MIL-STD-750A
		Method 3001.1

<u>Item</u>		<u>Test Method and Test Conditions</u>
3.2.2	$V_{EBO} = 10V$	<u>JS-6-T4</u> or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 60V$	<u>JS-6-T5.1</u> $I_C (V_{CE} = V_{CEX}) = 3A$ $V_{CC} = 60V, R_L = 19.6\Omega$ $L = 1.0mH^*, CR = 1N1202$ $V_{BB1} = 6V, R_{BB1} = 5\Omega$ $V_{BB2} = 1.5V, R_{BB2} = 5\Omega$ Pulse width = 1.0ms, Duty Cycle = 2% $R_S = 0.1\Omega, t_r \leq 50\mu s$ $t_f \leq 50 \mu s$ *Miller # 7871 in series with 7825-3
3.3.0	Current	
3.3.1	$I_C = 3A$	<u>JS-6-T6</u> $I_B = 0.6A, T_C = \leq 25^\circ C$
3.3.2	$I_B = 1A$	<u>JS-6-T8</u> $T_C = \leq 25^\circ C$
3.4.0	Power	
3.4.1	$P_{,T} = 5W$	<u>JS-6-T12</u> $T_C = \leq 100^\circ C$ $V_{CB} = 60V, I_C = 83mA$ Derating Factor = $0.05 W/^\circ C$
3.4.2	$P_{TM} = I_C V_{CC} = 180W$	<u>JS-6-T13</u> $T_C = 100^\circ C, V_{CC} = 60V, V_{BB} = 1.5V,$ $R_{BB} = 5\Omega$

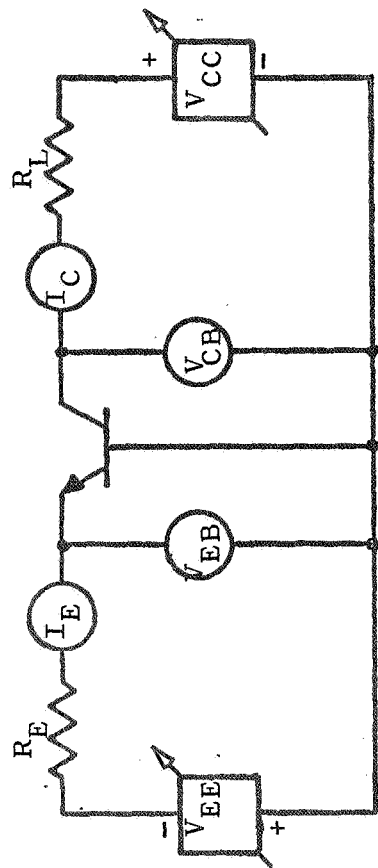
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.4.2 (Cont'd)	Pulse width = 1ms, Duty Cycle = $\leq 1\%$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> [See Figure 1] <u>Test Point:</u> [See 3.4.1]
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> [See Figure 2] <u>Test Points:</u> $T_C \leq 100^\circ C$, $V_{BB} = 1.5V$, $R_{BB} = 5\Omega$ $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, $I_C = 3A$ Duty Cycle $\leq 1\%$, $R_S = 0.1\Omega$ 1. For $t_p = 7.5ms$; $V_{CC} = 20V$ 2. For $t_p = 5.0ms$; $V_{CC} = 30V$ 3. For $t_p = 2.5ms$; $V_{CC} = 50V$ 4. For $t_p = 1ms$; $V_{CC} = 60V$
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<u>JS-6-T5-5.1</u> with $L=0$ and CR disconnected [See Figure 3] <u>Test Points:</u> $I_C = 3A$, $V_{CC} = 90V$, $R_{BB1} = 5\Omega$ $R_{BB2} = 5\Omega$, $V_{BB1} = 6V$, $V_{BB2} = 1.5V$ $T_C = 100^\circ C$; $t_f \leq 50\mu s$, Collector Current

<u>Item</u>		<u>Test Methods and Test Conditions</u>
3.6.1	(Cont'd)	$t_r \leq 50\mu s$ Collector Current $R_S = .1\Omega$
3.6.2	Clamped Inductive Load	<u>JS-6-T5-5.1</u> [See Figure 4] <u>Test Points:</u> $I_C = 3A$, $V_{CC} = 60V$, $R_L = 19.6\Omega$ $L = 1mH^*$, $R_{BB1} = 5\Omega$, $R_{BB2} = 5\Omega$ $V_{BB1} = 6V$, $V_{BB2} = 1.5V$, $t_p = 1ms$ $CR = 1N1202$, $T_C = 25^\circ C$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Duty Cycle = 2%, $R_S = 0.1\Omega$ *Miller # 7871 in series with 7825-3
3.6.3	Unclamped Inductive Load	<u>JS-6-T5-5.1</u> with CR disconnected [See Figure 5] <u>Test Points:</u> $R_{BB1} = 5\Omega$, $R_{BB2} = 5\Omega$, $R_S = .1\Omega$ $V_{BB1} = 6V$, $V_{BB2} = 1.5V$, $f = 20Hz$ $T_C = 25^\circ C$, $d = 10\%$ 1. $I_C = 3A$, $V_{CC} = 50V$, $R_L = 16.23\Omega$ $L = 15mH^*$ 2. $I_C = 0.9A$, $V_{CC} = 35V$, $R_L = 38.5\Omega$ $L = 60mH^{**}$ *Series Stancor C-2688 & C-2689 **Series 2 Stancor C-2686 & C-2688
3.7.0	Shorted Class B SOAR	[See Figure 6] <u>Test Point:</u> $I_{C(peak)} = 0.25A$, $V_{CC} = 60V$, $R_S = .1\Omega$ $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$ $T_C \leq 100^\circ C$

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.0.0	<u>Electrical</u> <u>Characteristic</u>	
	Maximum limits unless otherwise noted.	$T_C = 25^{\circ}\text{C}$ [unless otherwise noted]
	Technique:	
	DC - Continuous Operation	
	C.T. - Curve Tracer	
	P - 300 μs Pulse 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{\text{CEX}} = 750\mu\text{A}$	$V_{\text{CE}} = 80\text{V}$, $V_{\text{BE}} = -1.5\text{V}$, $T_C = 150^{\circ}\text{C}$ Technique - C.T.
4.1.2	$I_{\text{CEX}} = 150\mu\text{A}$	$V_{\text{CE}} = 80\text{V}$, $V_{\text{BE}} = -1.5\text{V}$ Technique - C.T.
4.1.3	$I_{\text{CBO}} = 150\mu\text{A}$	$V_{\text{CB}} = 80\text{V}$ Technique - C.T.
4.1.4	$I_{\text{EBO}} = 50\mu\text{A}$	$V_{\text{EB}} = 10\text{V}$ Technique - C.T.
4.1.5	$V_{[\text{BR}]\text{CEO}} = 60\text{V min}$	$I_C = 50\text{mA}$ Technique - C.T.
4.1.6	$I_{\text{CEO}} = 100\mu\text{A}$	$V_{\text{CE}} = 45\text{V}$ Technique - C.T.
4.1.7	$h_{\text{FE}} = 20 \text{ min}$ $h_{\text{FE}} = 60 \text{ max}$	$V_{\text{CE}} = 4\text{V}$, $I_C = 1\text{A}$ Technique - C.T.
4.1.8	$h_{\text{FE}} = 20 \text{ min}$	$V_{\text{CE}} = 4\text{V}$, $I_C = 1\text{A}$, $T_C = -55^{\circ}\text{C}$ Technique - C.T.

<u>Item</u>	<u>Test Methods and Test Conditions</u>
4.1.9 $V_{CE[sat]} = 0.3V$	$I_C = 1A, I_B = 0.1A$ Technique - C.T.
4.1.10 $V_{BE} = 1.2V$	$V_{CE} = 4; I_C = 1A$ Technique - C.T.
4.1.11 $V_{CE[sat]} = 1V$	$I_C = 3A, I_B = 0.3A$
4.1.12 $V_{BE[sat]} = 1.5V$	$I_C = 3A, I_B = 0.3A$ Technique - C.T.
4.2.4 $t_{on} = 1.0\mu s$	$V_{CC} = 12V, I_C = 1.0A, I_{B1} = 100mA$
4.2.5 $t_{off} = 1.5\mu s$	$V_{CC} = 12V, I_C = 1.0A, I_{B1} = 100mA,$ $I_{B2} = -50mA$
4.2.7 $\left h_{fe} \right _{min} = 1$ $\left h_{fe} \right _{max} = 6$	$V_{CE} = 4V, I_C = 0.1A$ $f = 1.0MHz$
5.0.0 <u>Thermal</u> <u>Characteristics</u>	
5.1.0 $\tau_J = 80ms \text{ min}$	$I_C = 1A, V_{CE} = 5V, T_C = 25^{\circ}C$ MIL-STD-750 Method 3146.1
5.2.0 $\theta_{J-C} = 20^{\circ}C/W$	$I_C = 1A, V_{CE} = 5V$ MIL-STD-750A Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

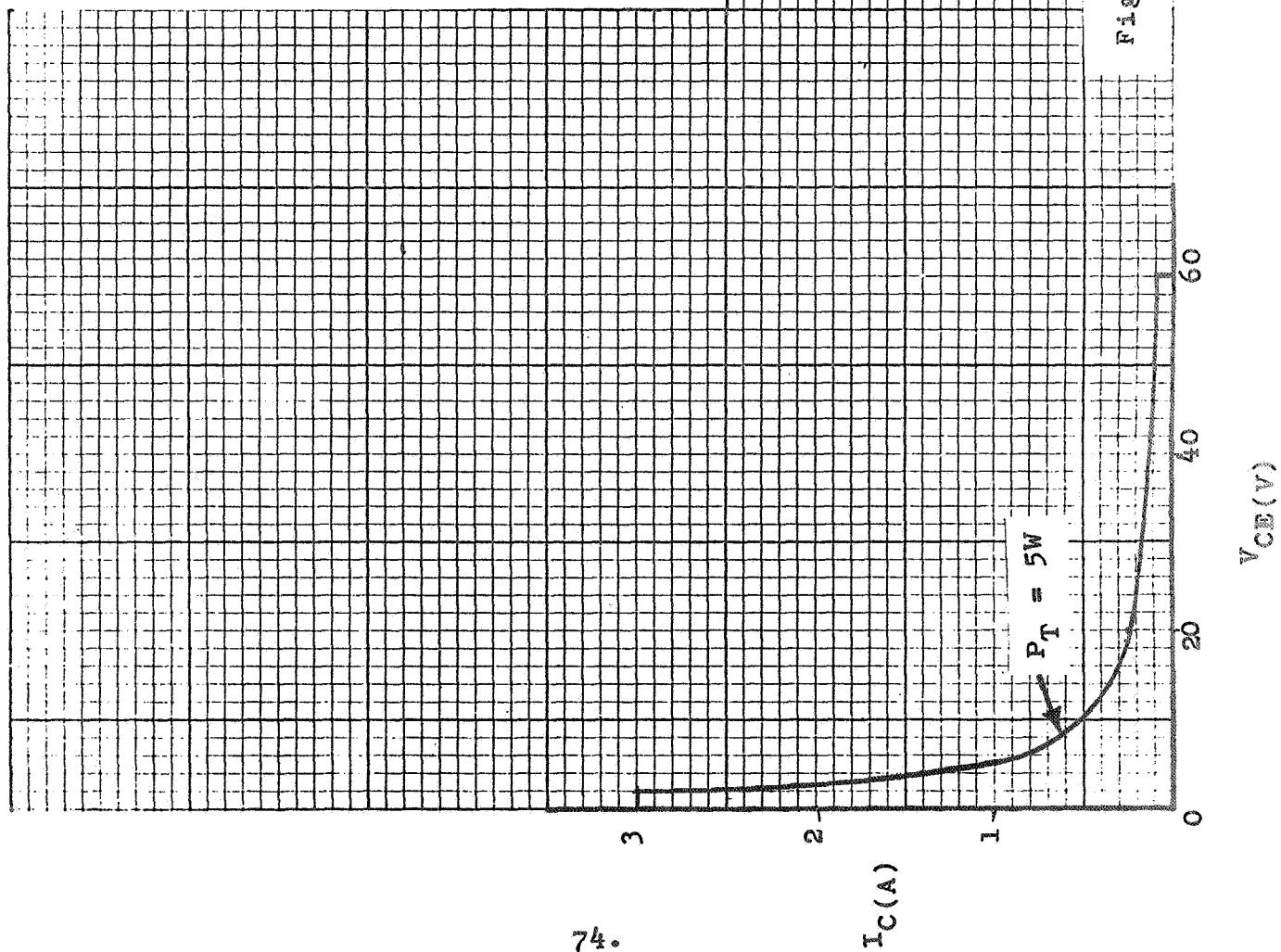
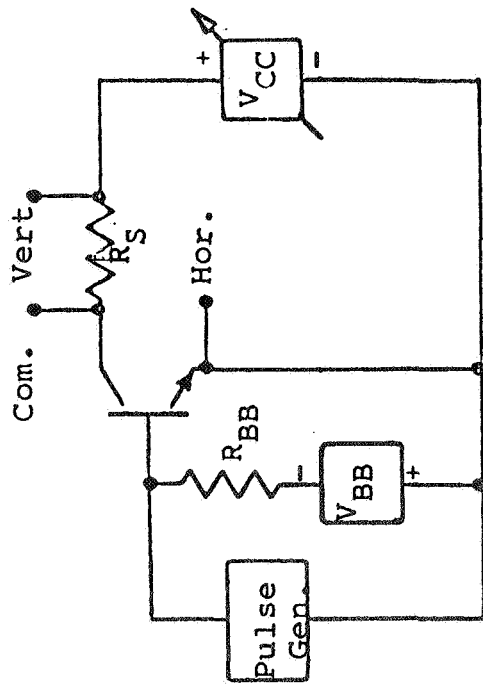
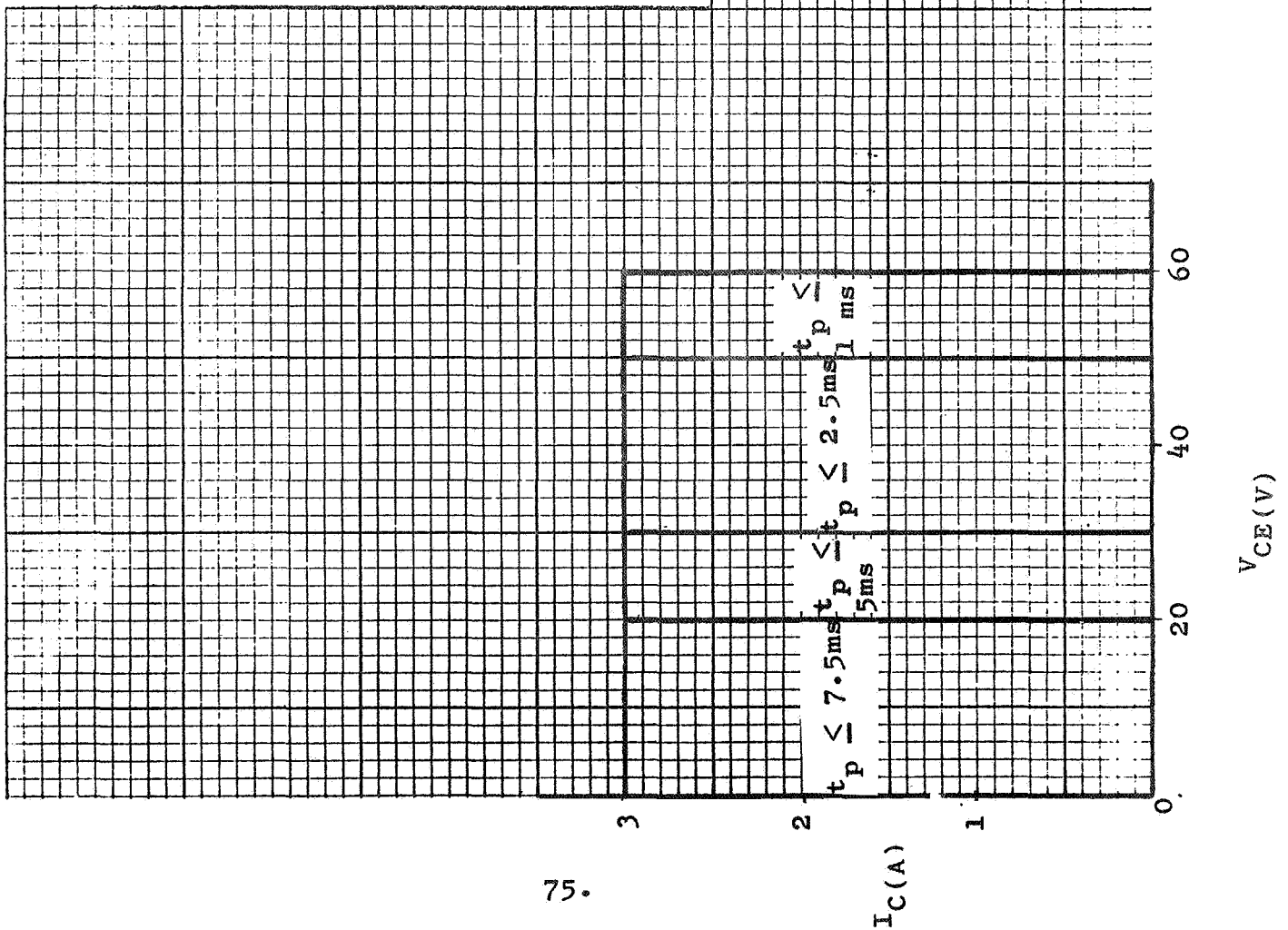


Figure 1

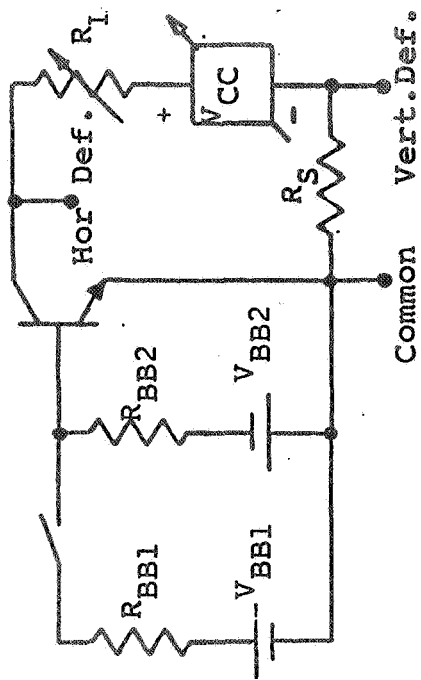
PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14



SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1

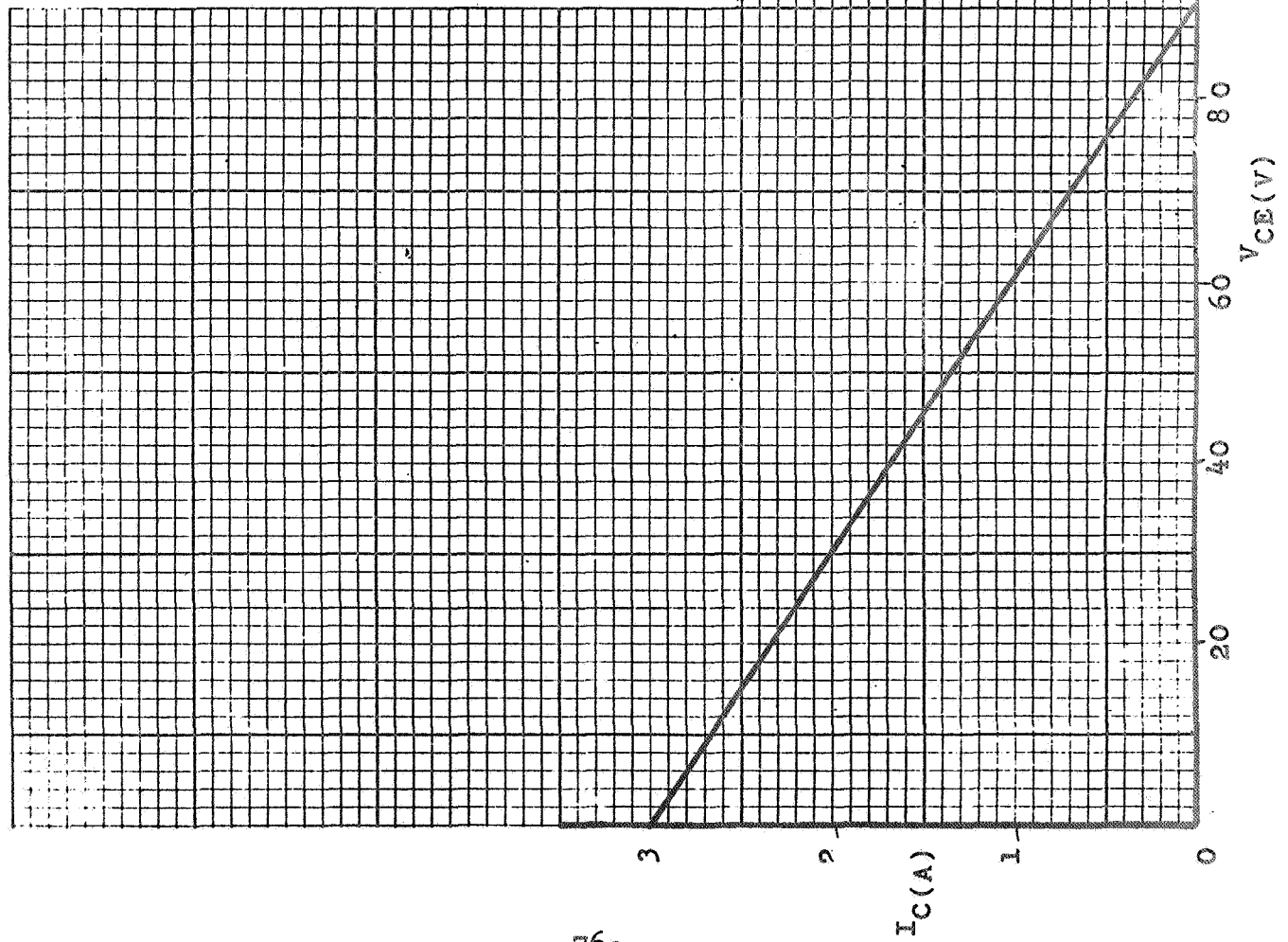
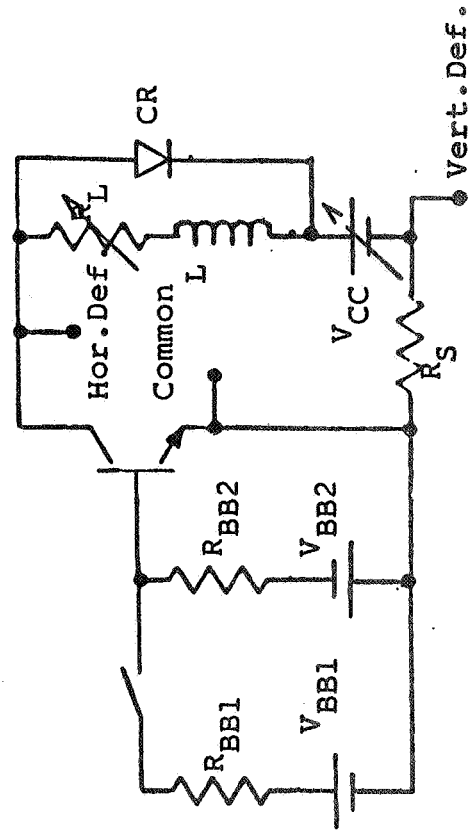


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

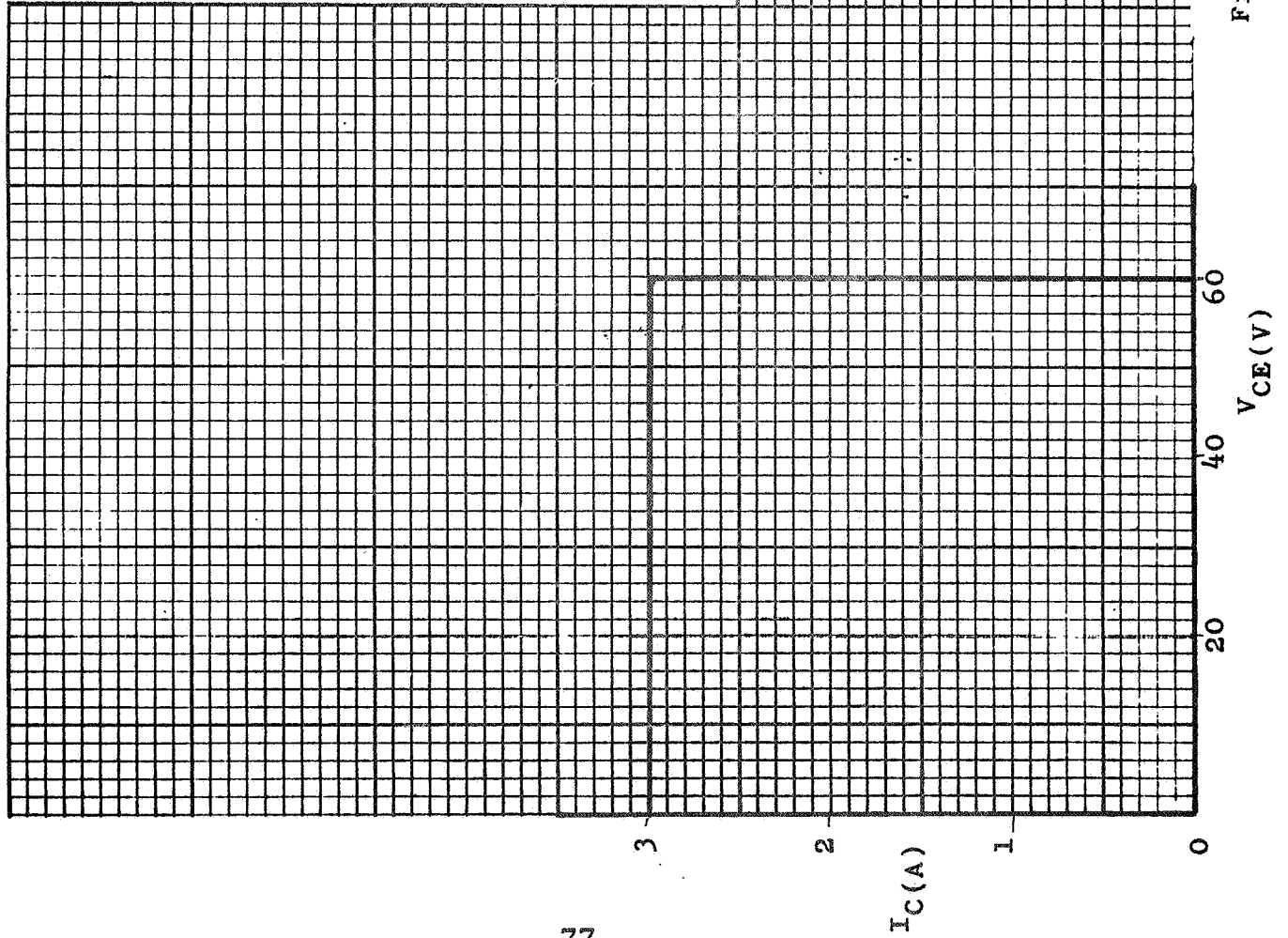
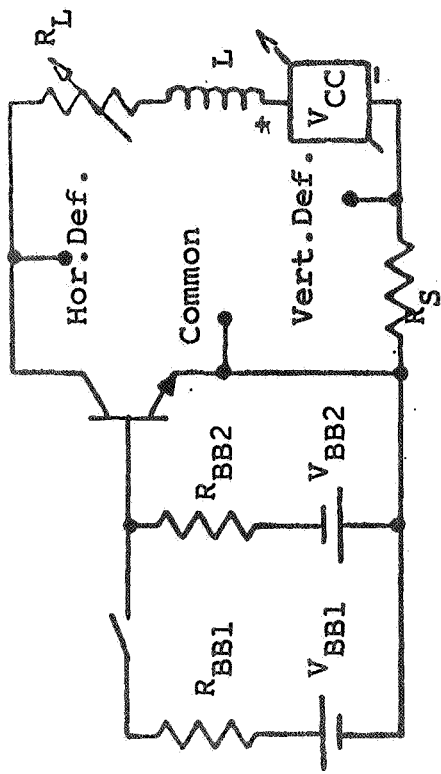


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

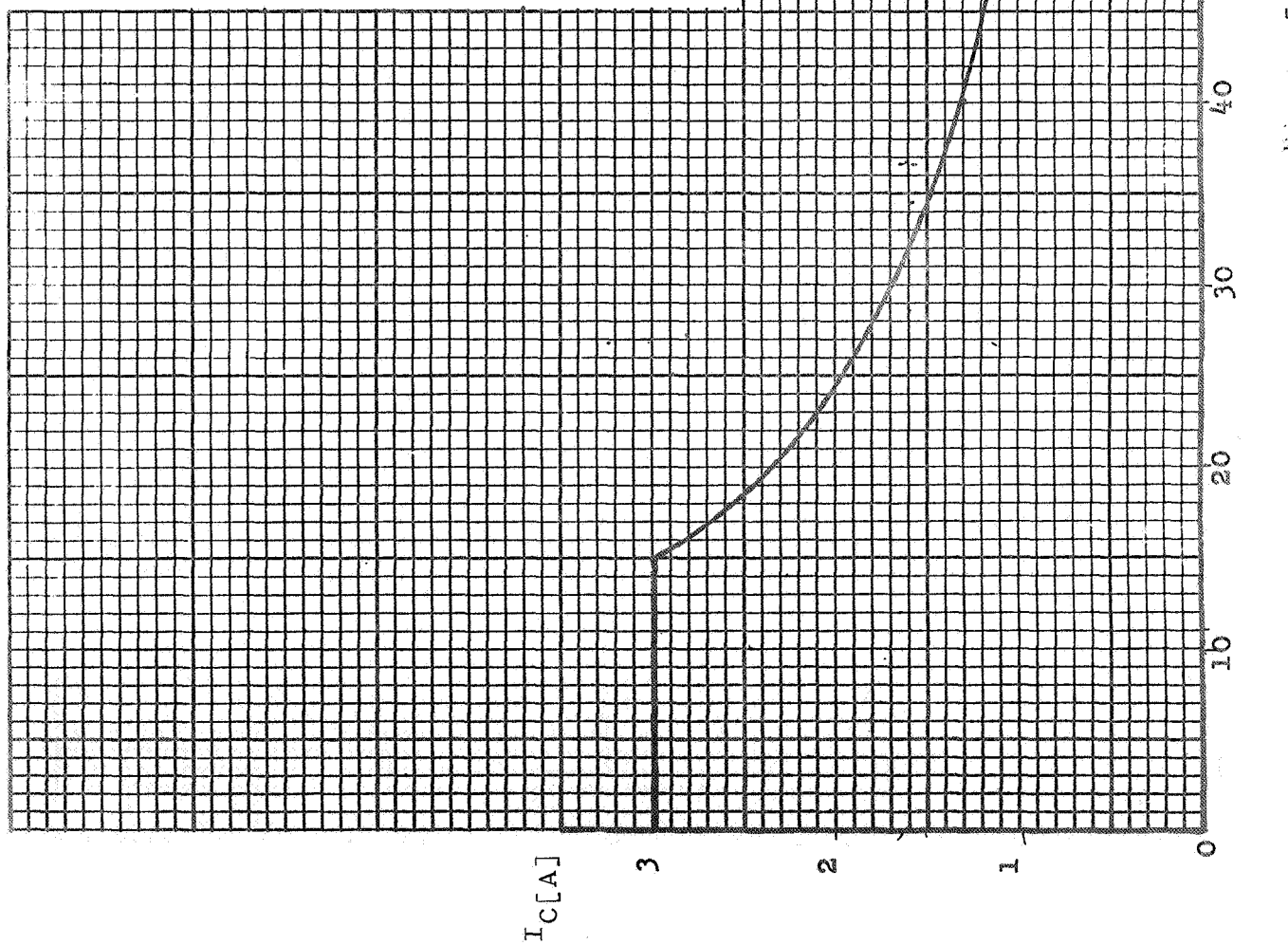
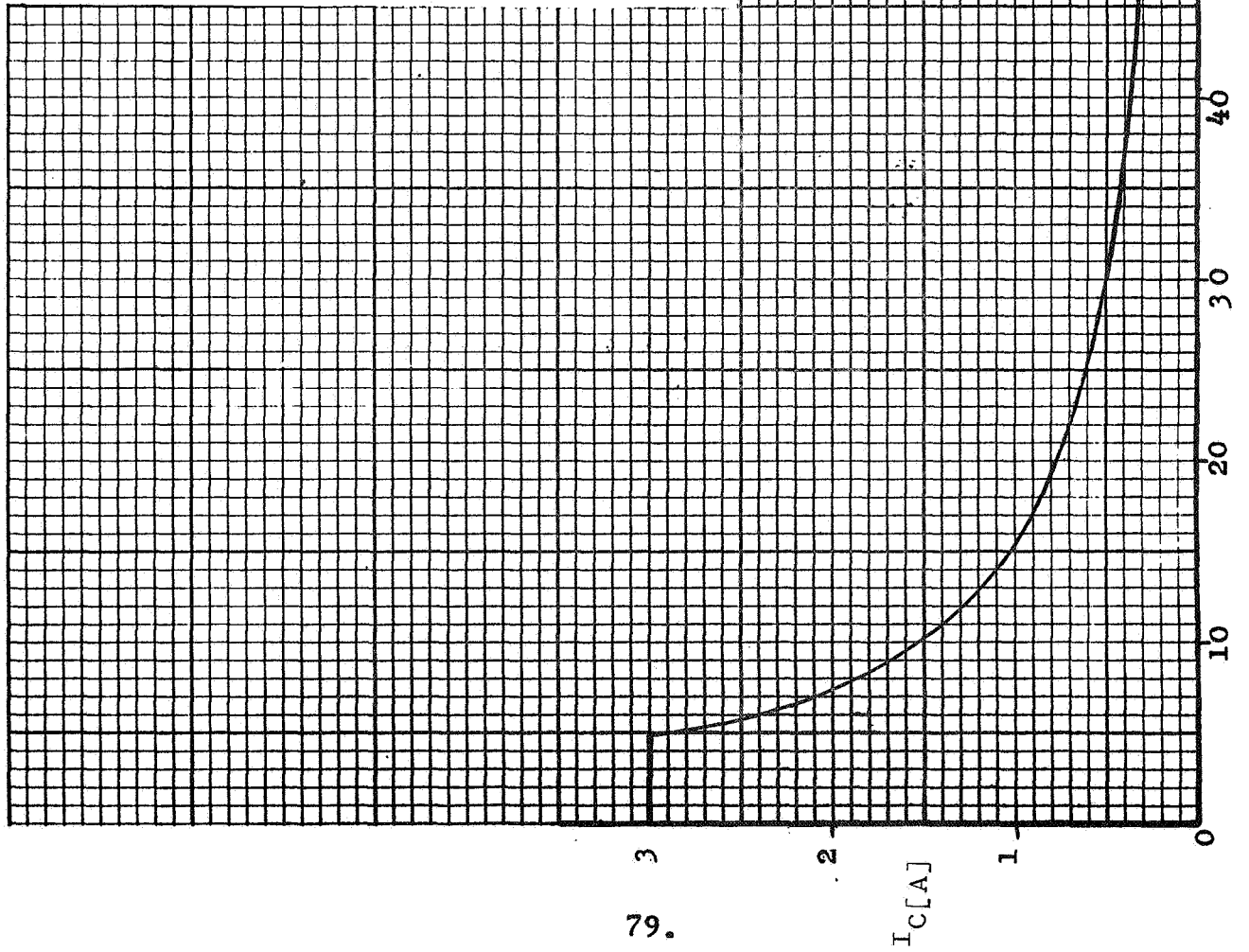
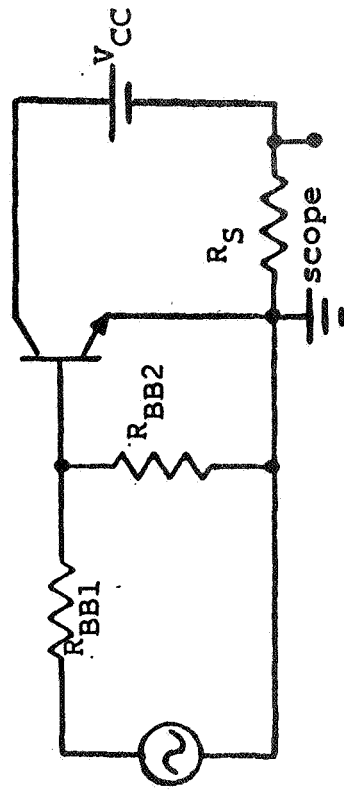


Figure 5

SHORTED CLASS B SOAR



V_{CE} [V]

Figure 6

Silicon Power Transistor

< Type 2N2126 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer C --

Performed for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract No. NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	Terminal Designation	
	1 - Base	
	2 - Emitter	
	3 - Collector	
	case - Collector	
2.2.1	Maximum Stud Torque - 100 in.lbs.	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{stg}(\max) = +175^{\circ}\text{C}$	<u>JS-6-T1.1</u>
	$T_{stg}(\min) = -65^{\circ}\text{C}$	<u>JS-6-T1.2</u>
3.1.2	$T_j = 175^{\circ}\text{C}$	<u>JS-6-T2</u>
	$T_C = 100^{\circ}\text{C}, V_{CB} = 100\text{V}, I_C = 1.67\text{A}$	
3.1.3	$T(\text{Lead}) = 230^{\circ}\text{C}$	Distance from case - 1/4 in., Time - 10s
3.2.0	Voltage	
3.2.1	$V_{CB0} = 200\text{V}$	<u>JS-5-T3</u> or MIL-STD-750A Method 3001.1 (See page 18)
3.2.2	$V_{EB0} = 15\text{V}$	<u>JS-6-T4</u> or MIL-STD-750A Method 3026.1 (See page 19)
3.2.3	$V_{CEX} = 180\text{V}$	<u>JS-6-T5-2.1</u>
	$I_C(V_{CE} = V_{CEX}) = 30\text{A}, V_{CC} = 180\text{V},$	
	$R_L = 6\Omega, L = 1\text{mH}^*, CR = 1\text{N1204},$	
	$V_{BB1} = 14\text{V}, R_{BB1} = 1\Omega, V_{BB2} = 8\text{V},$	
	$R_{BB2} = 3\Omega,$	
	Duty Cycle = 1%, $t_p = 1\text{ms}, R_s = 0.1\Omega$	
	*Miller No. 7870	

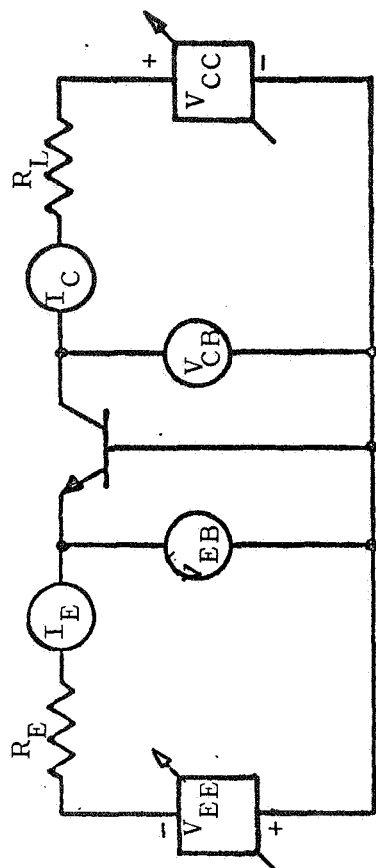
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.3.0 Current	
3.3.1 $I_C = 30A$	<u>JS-6-T6</u> $I_b = 6A, T_C = 25^{\circ}C$
3.3.2 $I_B = 10A$	<u>JS-6-T8</u> $T_C = 25^{\circ}C$
3.3.3 $I_E = 36A$	<u>JS-6-T10</u> $I_b = 6A, T_C = 25^{\circ}C$
3.4.0 Power	
3.4.1 $P_T = 167W$	<u>JS-6-T12</u> $T_C = 100^{\circ}C, V_{CB} = 175V, I_C = .93A$ Derating Factor - $2.22W/^{\circ}C$
3.4.2 $P_{TM} = I_C V_{CC} = 465W$	<u>JS-6-T13</u> $T_C = 100^{\circ}C, V_{CC} = 155V, V_{BB} = 8V,$ $R_{BB} = 3\Omega, I_C = 30A, \text{Pulse Width} = 100\mu s,$ Duty Cycle = 1%, $t_r \leq 50\mu s,$ $t_f = 50\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> <u>Test Point:</u> (See 3.4.1)
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> <u>Test Points:</u> $T_C = 100^{\circ}C, V_{BB} = 8V, R_{BB} = 3\Omega$ $t_r \leq 50\mu s, t_f \leq 50\mu s, I_C = 30A,$ Duty Cycle $\leq 1\%, R_S = 0.1\Omega$ 1. For $t_p = 10ms; V_{CC} = 50V$ 2. For $t_p = 1ms: V_{CC} = 90$ 3. For $t_p = 500\mu s: V_{CC} = 120V$ 4. For $t_p = 100\mu s: V_{CC} = 155V$

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	<u>JS-6-T5-2.1</u> with $L = 0$ and CR Disconnected <u>Test Points:</u> $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $V_{BB1} = 14V$, $V_{BB2} = 8V$, $T_C = 100^\circ C$, $t_f \leq 50\mu s$ Coll. Current, $t_r \leq 50\mu s$ Coll. Current, $R_S = 0.1\Omega$, $I_C = 30A$, $V_{CC} = 200V$
3.6.2	Clamped Inductive Load	<u>JS-6-T5-2.1</u> <u>Test Points:</u> (See 3.2.3)
3.6.3	Unclamped Inductive Load	<u>JS-6-T5-2.1</u> and CR disconnected <u>Test Points:</u> 1. $V_{BB1} = 14V$ $L = 0.2mH^*$ $R_{BB1} = 1\Omega$ $R_L = 0.4\Omega$ $V_{BB2} = 8V$ $V_{CC} = 16.5V$ $R_{BB2} = 3\Omega$ $f = 60Hz$ $R_S = 0.1\Omega$ $d = 10\%$ 2. $V_{BB1} = 7V$ $L = 1mH^{**}$ $R_{BB1} = 1\Omega$ $R_L = 2.1\Omega$ $V_{BB2} = 8V$ $V_{CC} = 10.5V$ $R_{BB2} = 3\Omega$ $f = 60Hz$ $R_S = 0.1\Omega$ $d = 10\%$ *Miller No. 7828 **Miller No. 7830 in series with 7871

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
3.7.0	Shorted Class B SOAR	<p>[See Figure 6]</p> <p><u>Test Points:</u></p> <p>$I_{Cpeak} = 5.4A$, $V_{CC} = 92.5V$, $R_S = 0.1\Omega$ $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$, $T_C = 100^\circ C$</p>
4.0.0	<u>Electrical</u> <u>Characterisitics</u>	$T_C = 25^\circ C$ [unless otherwise noted]
	Maximum limits unless otherwise noted	
	Technique:	
	DC - Continuous Operation	
	C.T. - Curve Tracer	
	P - 300 μs Pulse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEX} = 30mA$	<p>$V_{CEX} = 200V$, $V_{BE} = -1.5V$, Technique - C.T., $T_C = 175^\circ C$</p>
4.1.2	$I_{CEO} = 100mA$	$V_{CEO} = 175V$, Technique - C.T.
4.1.3	$I_{EBO} = 25mA$	<p>$V_{EBO} = 15V$, $T_C = 175^\circ C$ Technique - C.T.</p>
4.1.4	$V_{CEO} = 185V$ min	<p><u>JS-6-T5-2.1</u> and CR disconnected $I_C = 5A$, $R_{BB1} = 3\Omega$, $V_{BB1} = 3V$, $R_{BB2} = \infty\Omega$, $d = 50\%$, $f = 60Hz$, $L = 5mH$, $R_L = 0.1\Omega$, $R_S = 0.1\Omega$ Adjust V_{CC} for specified I_C</p>
4.1.5	$h_{FE} = 10$ min	$V_{CE} = 4V$, $I_C = 20A$ Technique-C.T.
4.1.6	$V_{CE(sat)} = 1.5V$	$I_C = 20A$, $I_B = 4A$, Technique - C.T.
4.1.7	$V_{BE(sat)} = 2.5V$	$I_C = 20A$, $I_B = 4A$, Technique - C.T.

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.2.0	Dynamic	
4.2.1	$t_{on} = 20\mu s$	$V_{CC} = 12V, I_C = 20A, I_{B1} = 5A$
4.2.2	$t_{off} = 25\mu s$	$V_{CC} = 12V, I_C = 20A, I_{B2} = 5A$
4.2.3	$f_{hfe} = \begin{matrix} 8KHz & \text{min} \\ 32KHz & \text{max} \end{matrix}$	$I_C = 5A, V_{CE} = 12V$
5.0.0	<u>Thermal Characteristics</u>	
5.1.0	$T_{jmin} = 45ms$	$I_C = 2A, V_{CE} = 10V, T_C = 25^{\circ}C$ MIL-STD-750, Method 3146.1
5.2.0	$\theta_{JC} = 0.45^{\circ}C/W$	$I_C = 2A, V_{CB} = 10V$ MIL-STD-750A, Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$
 Test Circuit: JS-6-T12

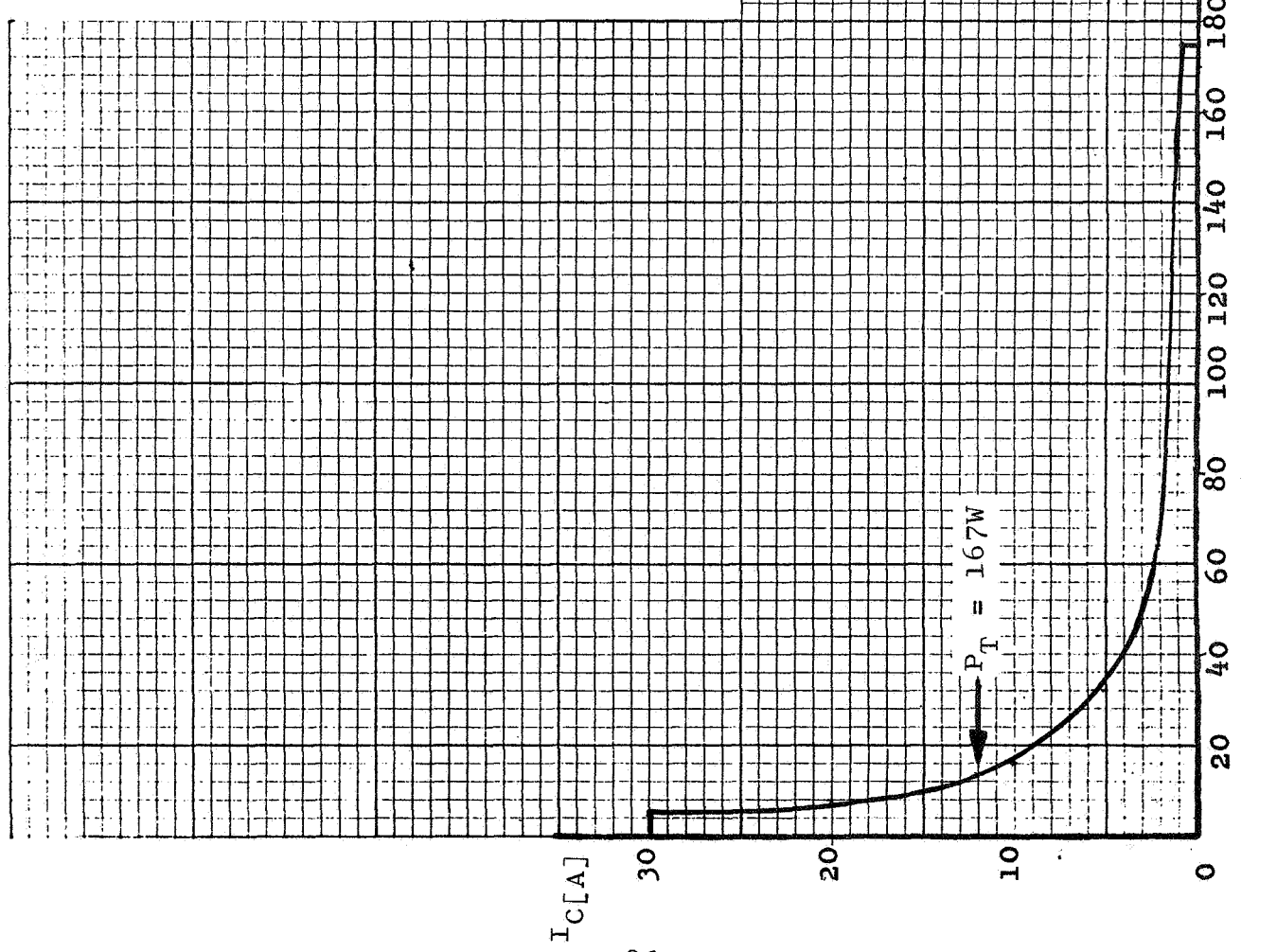
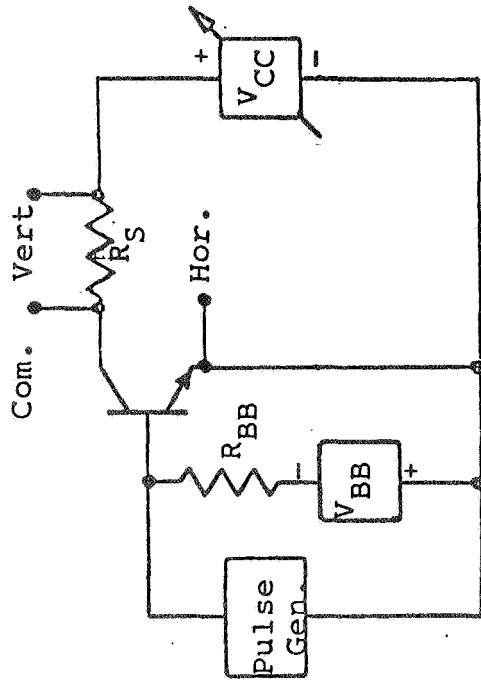


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

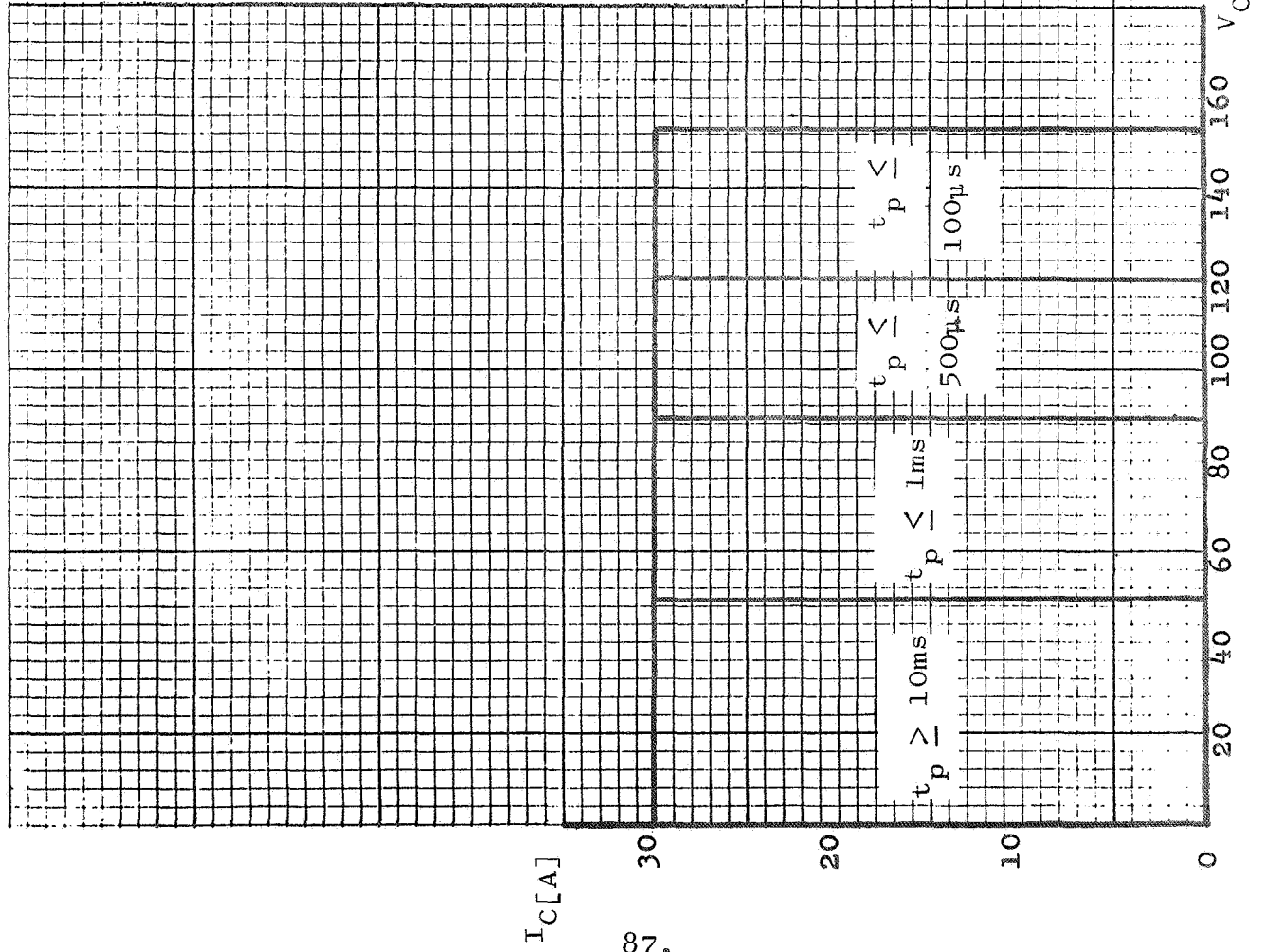


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

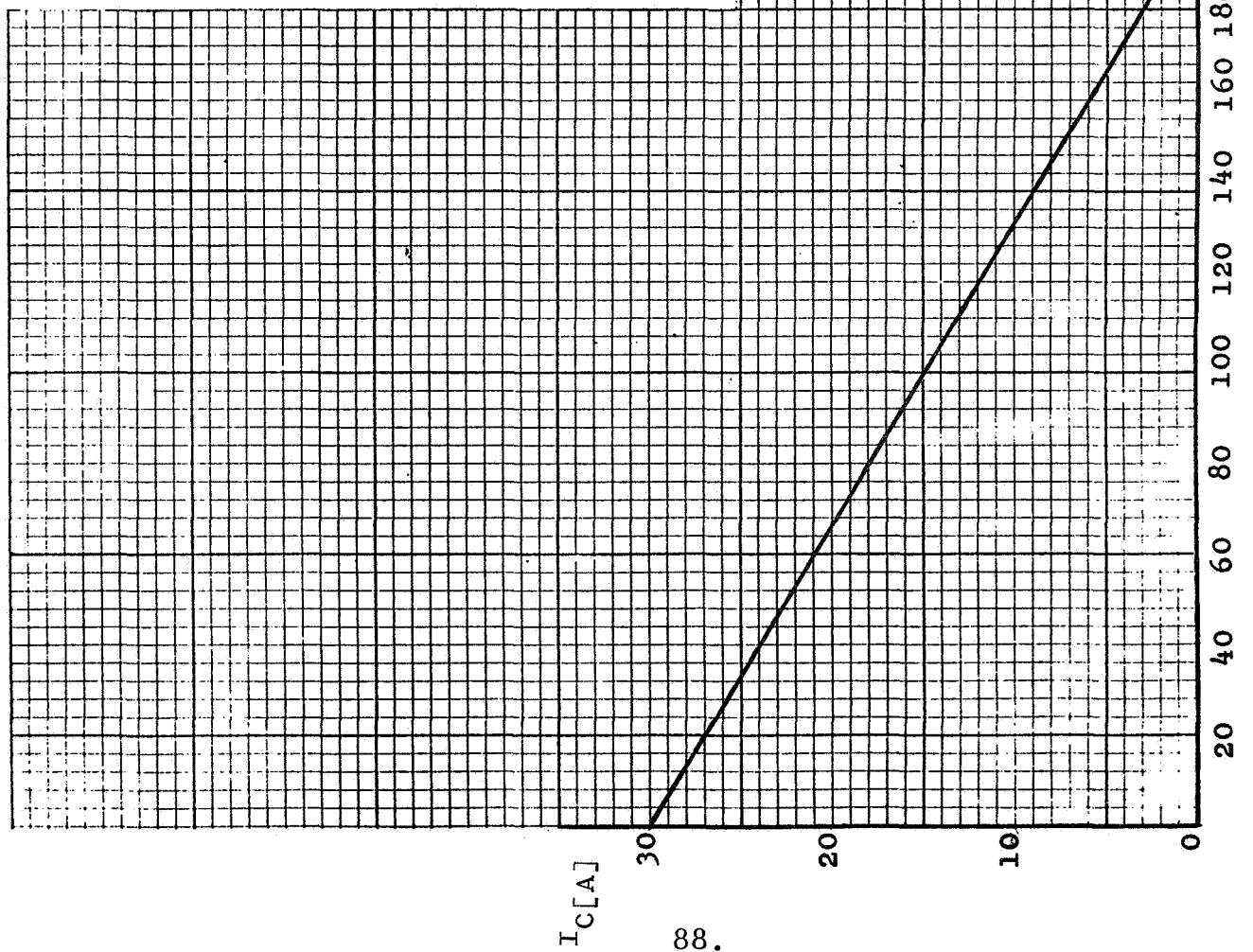
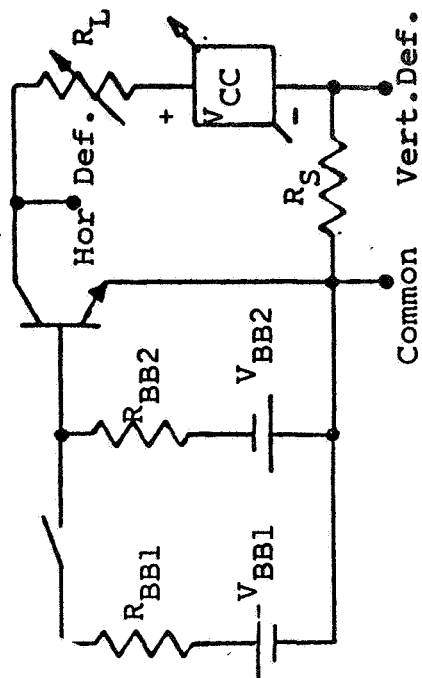
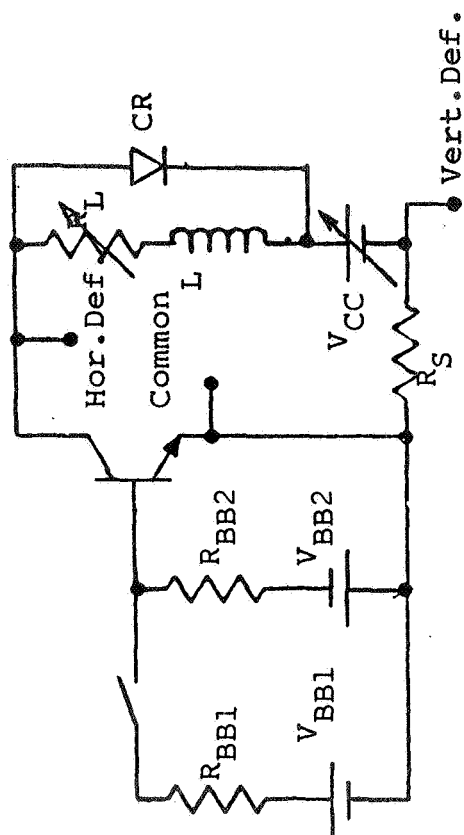


Figure 3



Test Circuit: JS-6-T5.2.1

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

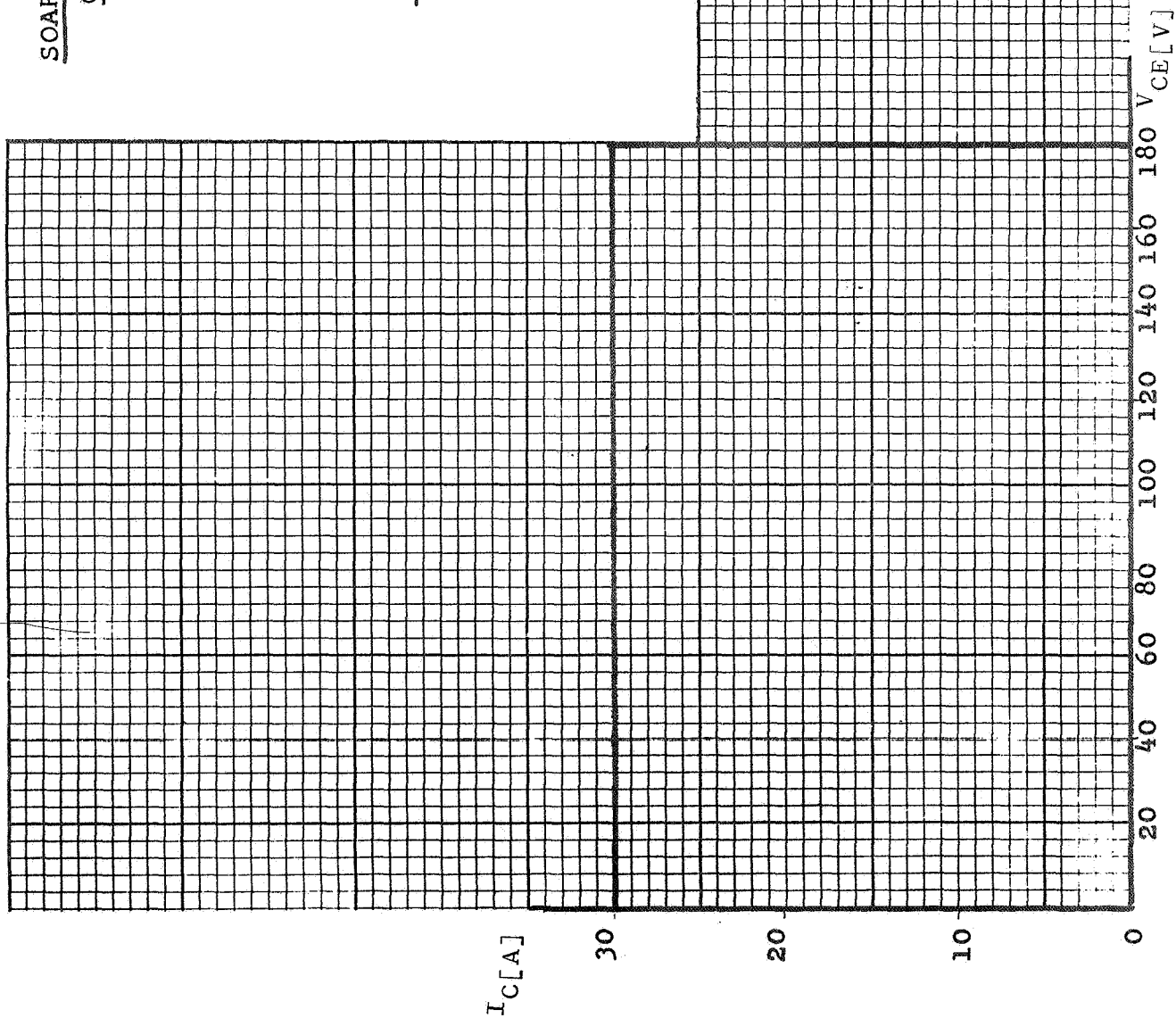
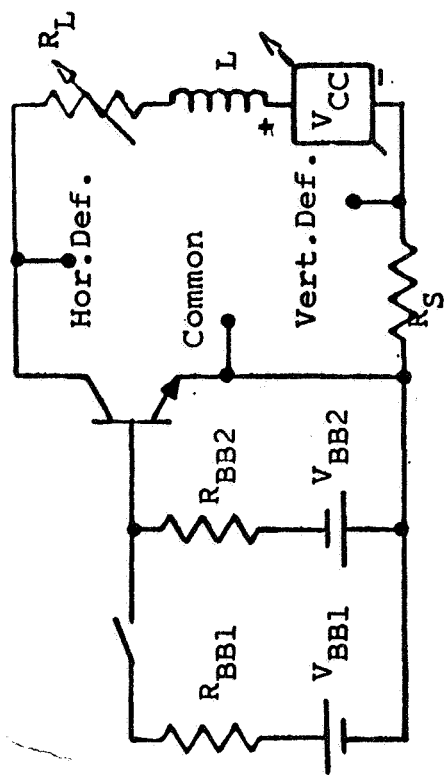


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

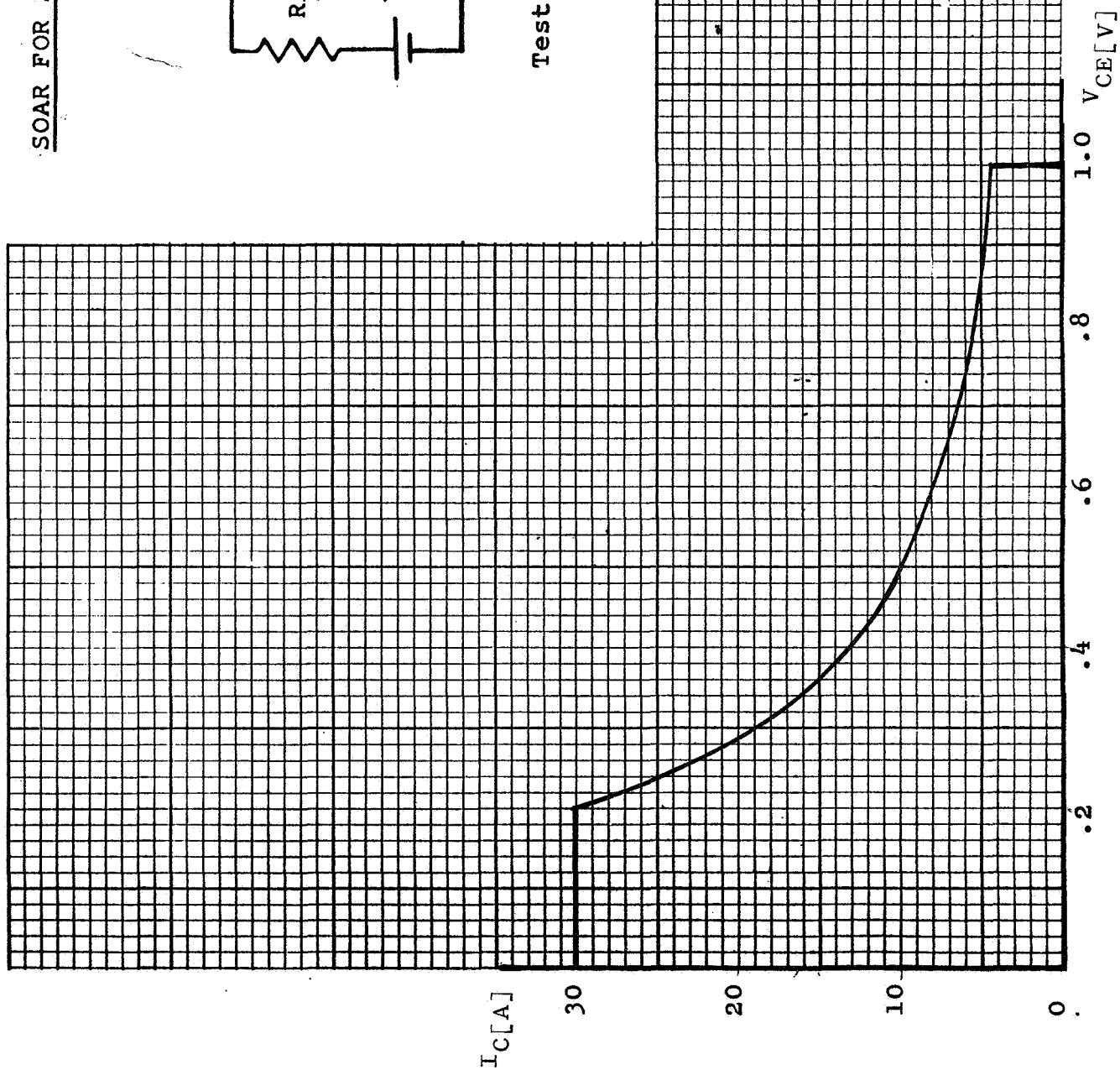


Figure 5

SHORTED CLASS B SOAR

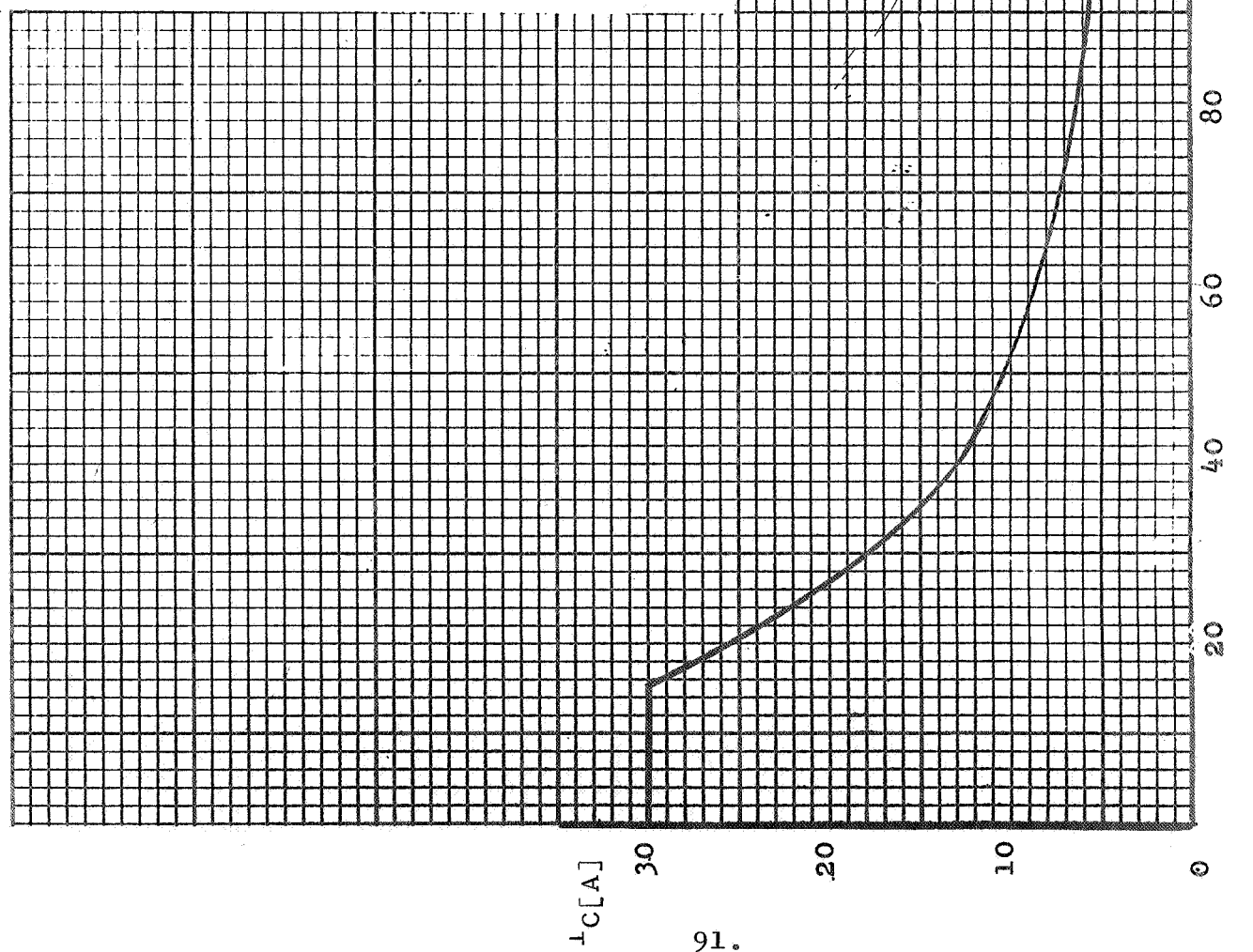
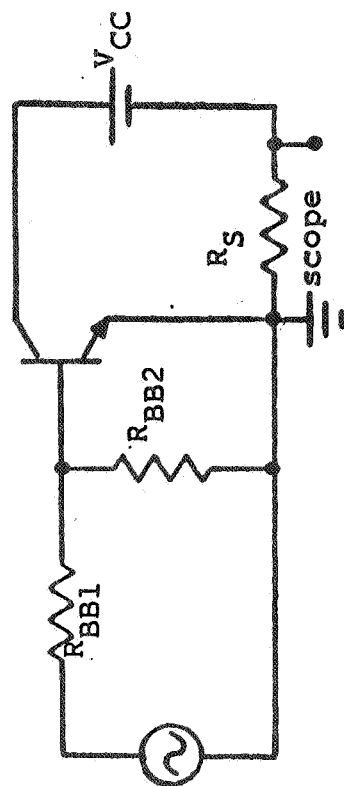


Figure 6

SILICON POWER TRANSISTOR

< Type 2N657A >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer E --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Method and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline - TO-5	
2.2.0	Terminal Designation	
	1 - Emitter	
	2 - Base	
	3 - Collector	
	case - Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = 200^{\circ}C$	JS-6-T1.2 [JEDEC publication No. 65 "Test Procedures for Verification of Maximum Ratings of Power Transistors"]
	$T_{STG(min)} = 200^{\circ}C$	
3.1.2	$T_J(max) = 200^{\circ}C$	JS-6-T2
		$T_C = 100^{\circ}C$, $V_{CB} = 100V$, $I_C = 28.6mA$
3.1.3	$T(Lead) = 260^{\circ}C$	Distance from case = 1/16 in.
		Time = 10s
3.2.0	Voltage	$T_C = 25^{\circ}C$
3.2.1	$V_{CBO} = 100V$	JS-6-T3 or MIL-STD-750A, method 3001.1
3.2.2	$V_{EBO} = 8V$	JS-6-T4 of MIL-STD-750A, method 3026.1
3.2.3	$V_{CEX} = 100V$	JS-6-T5
		$I_C (V_{CE} = V_{CEX}) = 0.5A$, $V_{CC} = 100V$,
		$R_L = 190\Omega$

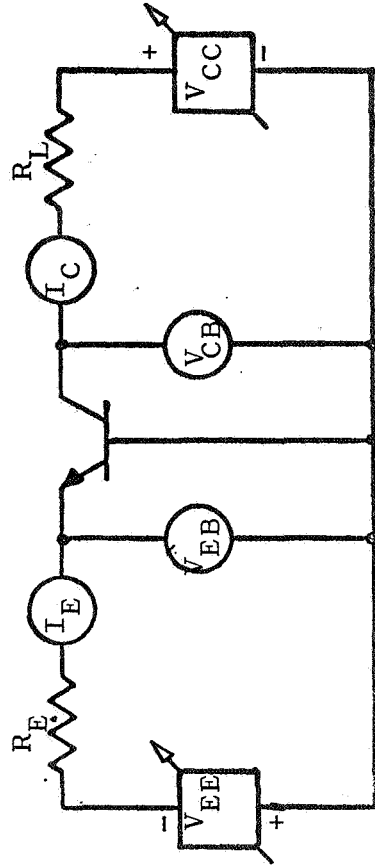
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.2.3 V_{CEX} [cont'd]	$L = 10\text{mH}$; 0.11Ω (Stancor C-2688), $CR = 1\text{N}1204$, $V_{BB1} = 10.1\text{V}$, $R_{BB1} = 33\Omega$ $V_{BB2} = 6.5\text{V}$, $R_{BB2} = 100\Omega$, $t_p = 1\text{ms}$, $R_S = 1\Omega$, Duty Cycle $\leq 1\%$
3.3.0 Current	
3.3.1 $I_C = 500\text{mA}$	<u>JS-6-T6</u> $I_B = 50\text{mA}$, $T_C = 25^\circ\text{C}$
3.2.2 $I_B = 250\text{mA}$	<u>JS-6-T8</u> $T_C = 25^\circ\text{C}$
3.3.3 $I_E = 550\text{mA}$	<u>JS-6-T10</u> $I_B = 50\text{mA}$, $T_C = 25^\circ\text{C}$
3.4.0 Power	
3.4.1 $P_T = 2.86\text{W}$	<u>JS-6-T13</u> $T_C = 100^\circ\text{C}$, $V_{CC} = 100\text{V}$, $I_C = 0.5\text{A}$ $V_{BB} = 6.5\text{V}$, $R_{BB} = 100\Omega$, Pulse Width 0.5ms Duty Cycle $\leq 1\%$, $t_r \leq 50\mu\text{s}$, $t_f \leq 50\mu\text{s}$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> [See Figure 1] $T_C = 100^\circ\text{C}$ <u>Test Points:</u> [See 3.1.2]

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.5.2 Pulsed Forward Biased SOAR	<p><u>JS-6-T14</u> [See Figure 2]</p> <p>$T_C = 100^{\circ}\text{C}$, $I_C = 0.5\text{A}$, $R_S = 0.1\Omega$</p> <p>$V_{BB} = 6.5\text{V}$, $R_{BB} = 100\Omega$, $t_r \leq 50\mu\text{s}$, $t_f \leq 50\mu\text{s}$, Duty Cycle $\leq 1\%$</p> <p><u>Test Points:</u></p> <ol style="list-style-type: none"> 1. For $t_p \leq 5\text{ms}$, $V_{CC} = 35\text{V}$ 2. For $t_p \leq 2\text{ms}$, $V_{CC} = 50\text{V}$ 3. For $t_p \leq 1\text{ms}$, $V_{CC} = 65\text{V}$ 4. For $t_p \leq 0.5\text{ms}$, $V_{CC} = 100\text{V}$
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<p><u>JS-6-T2.1</u> with L - 0 and CR disconnected [See Figure 3]</p> <p>$T_C = 100^{\circ}\text{C}$</p> <p><u>Test Points:</u></p> <p>$t_r \leq 50\mu\text{s}$, $t_f \leq 50\mu\text{s}$, $I_C = 0.5\text{A}$, $V_{CC} = 100\text{V}$, $R_S = 0.1\Omega$, $R_{BB1} = 33\Omega$ $R_{BB2} = 100\Omega$, $V_{BB1} = 10.1\text{V}$, $V_{BB2} = 6.5\text{V}$</p>
3.6.2 Clamped Inductive Load	<p><u>JS-6-T5-2.1</u> [See Figure 4]</p> <p>$T_C = 25^{\circ}\text{C}$</p> <p><u>Test Points:</u> [See 3.2.3]</p>
3.6.3 Unclamped Inductive Load	<p><u>JS-6-T5-2.1</u> and CR disconnected [See Figure 5]</p> <p>$T_C = 25^{\circ}\text{C}$</p>

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.3 Unclamped Inductive Load [cont'd]	$f = 1\text{Hz}$, Duty Cycle $\leq 5\%$, $R_S = 0.1\Omega$ $R_{BB1} = 33\Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 10.1\text{V}$, $V_{BB2} = 6.5\text{V}$ 1. $L = 50\text{mH}$; 0.424Ω [series 2-Stancor C-2686], $I_C = 0.5\text{A}$, $V_{CC} = 9\text{V}$, $R_L = 9\Omega$ 2. $I_C = 0.15\text{A}$, $V_{CC} = 8\text{V}$, $R_L = 34\Omega$ $L = 600\text{mH}$; 6Ω [series 2-TRIAD C-47U]
3.7.0 Shorted Class B SOAR	[See Figure 6] <u>Test Points:</u> $I_{C\text{peak}} = 50\text{mA}$, $V_{CC} = 80\text{V}$, $R_S = 1\Omega$ $R_{BB1} = 10\Omega$, $R_{BB2} = 5\Omega$, $f \geq 20\text{Hz}$, $T_C = 100^\circ\text{C}$
4.0.0 <u>Electrical Characteristics</u>	$T_C = 25^\circ\text{C}$ [unless otherwise noted]
Maximum Limits unless otherwise noted	
Technique:	
DC - Continuous Operation	
C.T. - Curve Tracer	
P - $300\mu\text{s}$ Pulse, 2% Duty Cycle	

Item	Test Methods and Test Conditions	
4.1.0	Static	
4.1.1	$I_{CEO} = 100\mu A$	$V_{CEO} = 100V$, Technique - C.T.
4.1.2	$I_{CBO} = 10\mu A$	$V_{CBO} = 30V$, Technique - C.T.
4.1.3	$I_{CBO} = 250\mu A$	$V_{CBO} = 30V$, $T_C = 150^{\circ}C$ Technique - C.T.
4.1.4	$V_{(BR)CEO} = 100V$	$I_C = 10mA$, Technique - C.T.
4.1.5	$V_{CBO} = 100V$	$I_C = 100\mu A$, Technique - C.T.
4.1.6	$V_{EBO} = 8V$	$I_E = 250\mu A$, Technique - C.T.
4.1.7	$h_{FE} = 30 \text{ min}$ 90 max	$V_{CE} = 10V$, $I_C = 200mA$ Technique = C.T.
4.1.8	$h_{FE} = 20 \text{ min}$	$V_{CE} = 10V$, $I_C = 0.5A$, Technique - P
4.1.9	$V_{CE(sat)} = 2V$	$I_C = 200mA$, $I_B = 40mA$, Technique - C.T.
4.1.10	$V_{CE(sat)} = 4V$	$I_C = 0.5A$, $I_B = 0.1A$, Technique - C.T.
4.1.11	$V_{BE(sat)} = 3.5V$	$I_C = 0.5A$, $I_B = 0.1A$, Technique - C.T.
4.1.12	$h_{1E} = 200ohms$	$V_{CE} = 10V$, $I_B = 8mA$, Technique - P
4.2.0	Dynamic	
4.2.1	$f_{hfe} = 50KHz(\text{min})$ $200KHz(\text{max})$	$I_C = 50mA$, $V_{CE} = 10V$
5.0.0	Thermal Characteristics	
5.1.0	$\tau_{J(\text{min})} = 250ms$	$I_C = 0.2A$, $V_{CE} = 5V$, $T_C = 25^{\circ}C$; MIL-STD-750 Method 3146.1
5.2.0	$\theta_{J-C(\text{max})} = 35^{\circ}C/W$	$I_C = 0.2A$, $V_{CE} = 5V$, $T_C = 25^{\circ}C$; MIL-STD-750 Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

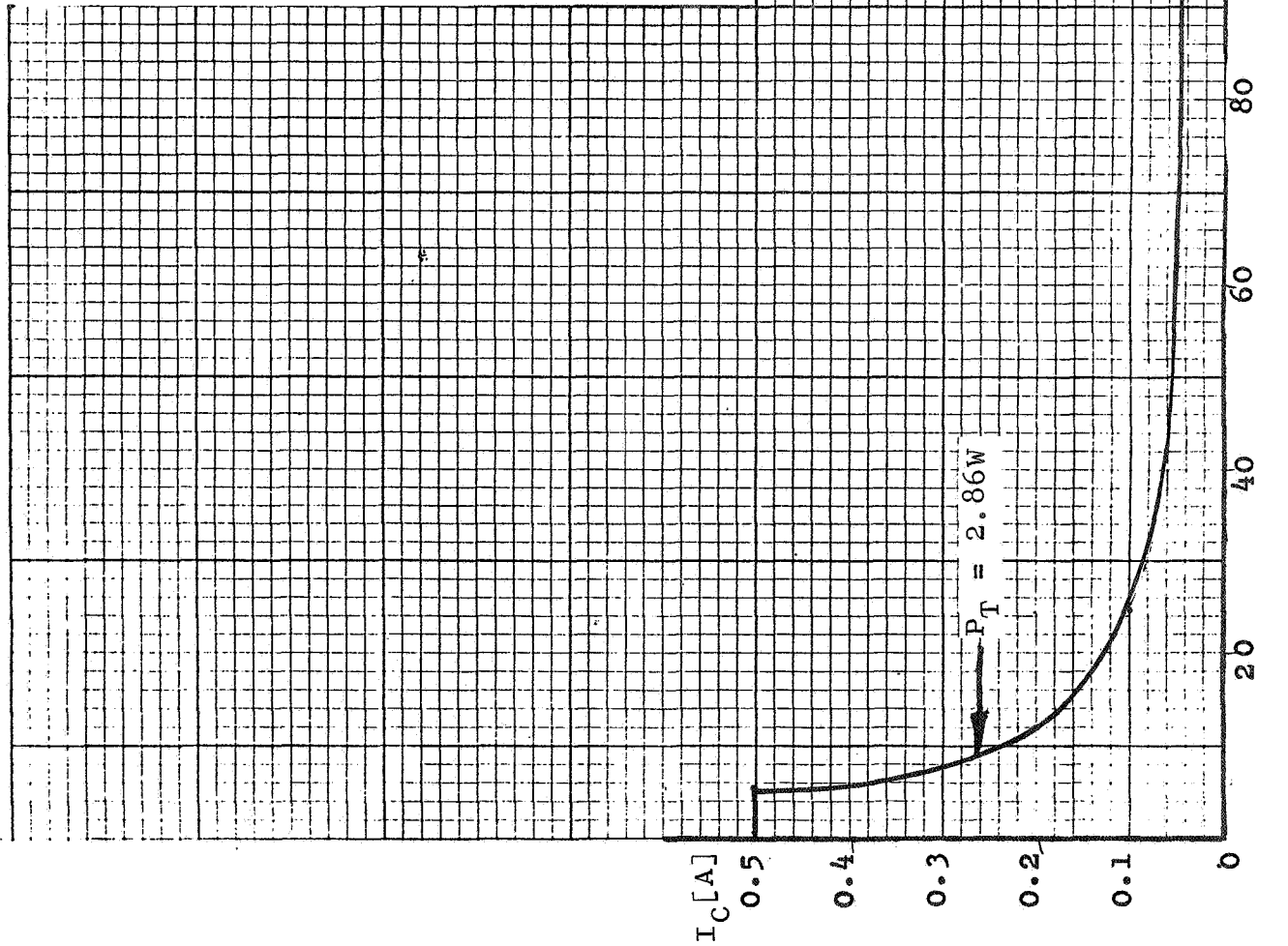
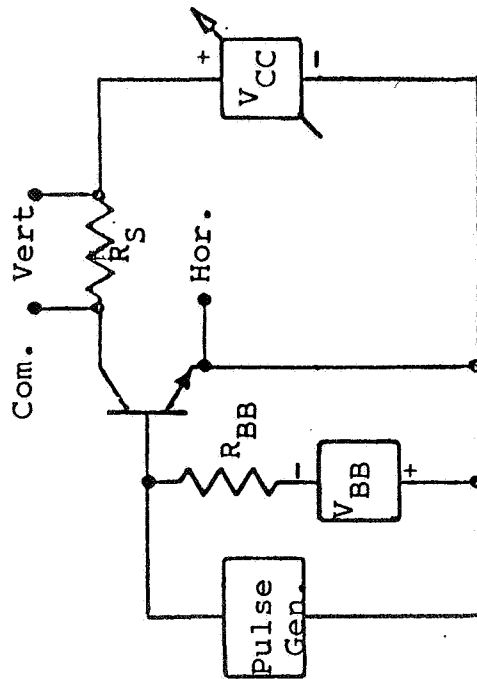


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

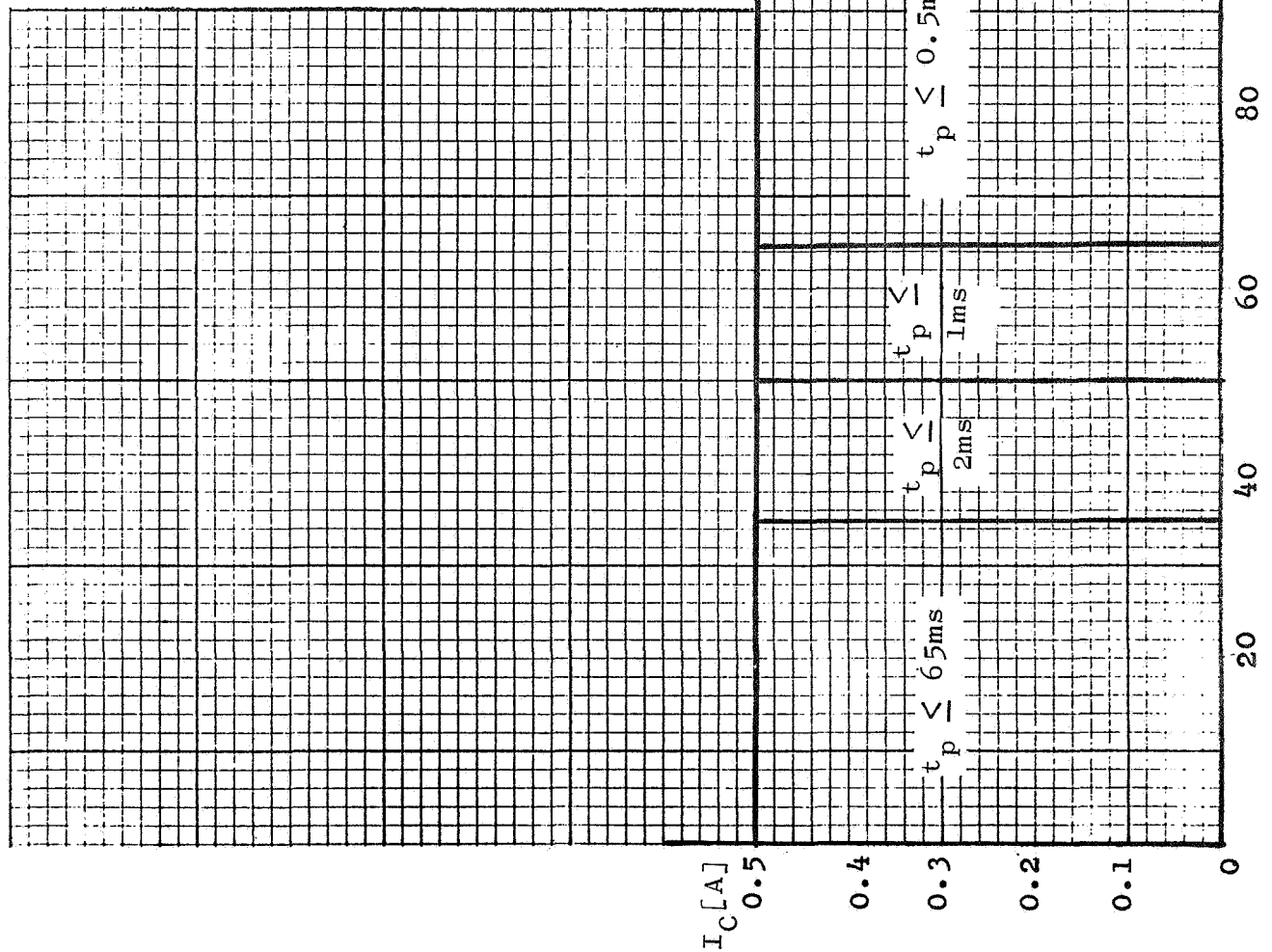


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

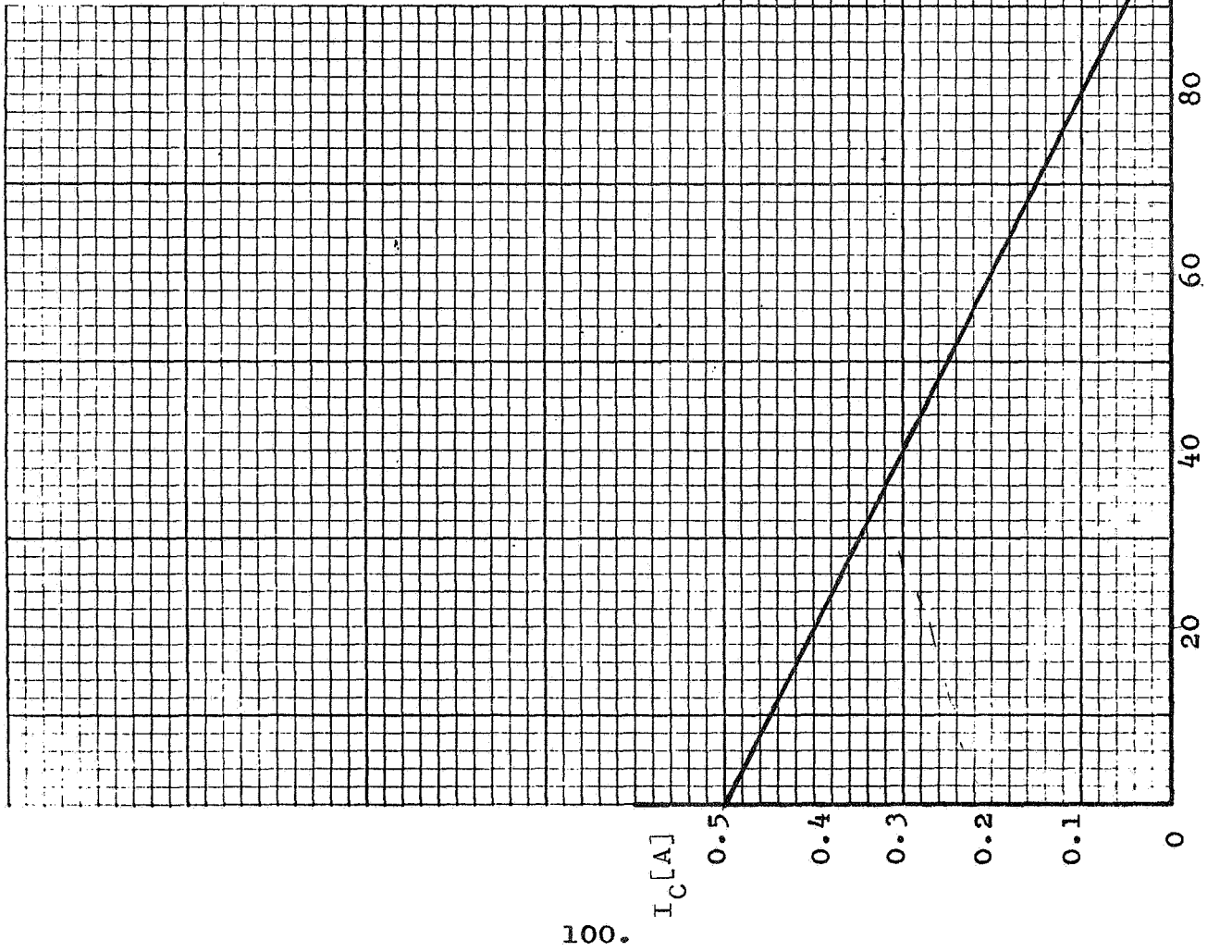
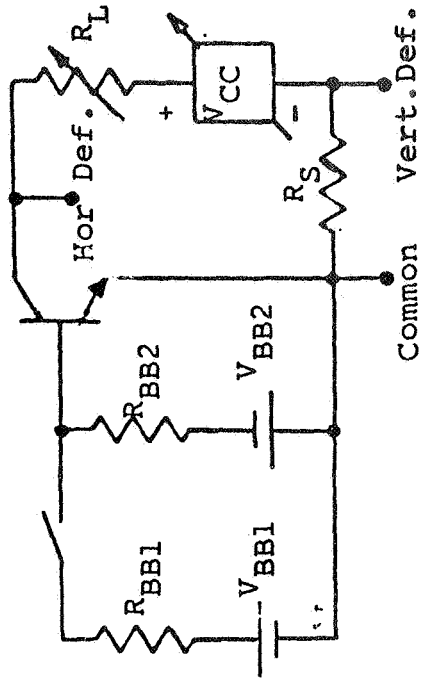
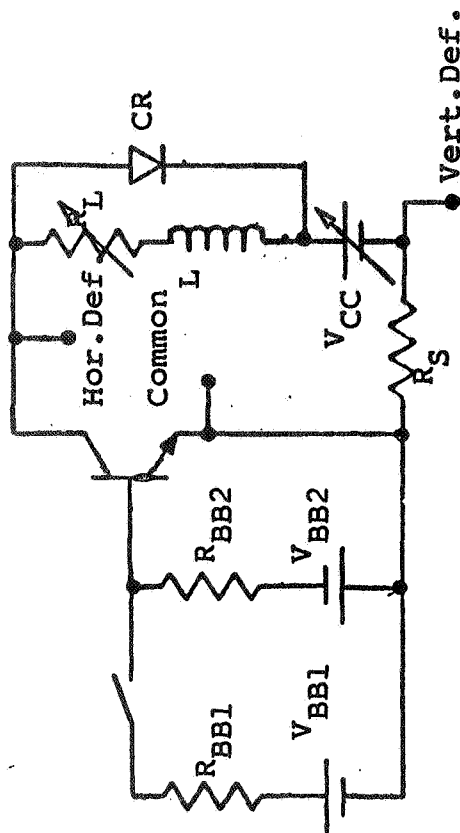


Figure 3



Test Circuit: JS-6-T5.2.1

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

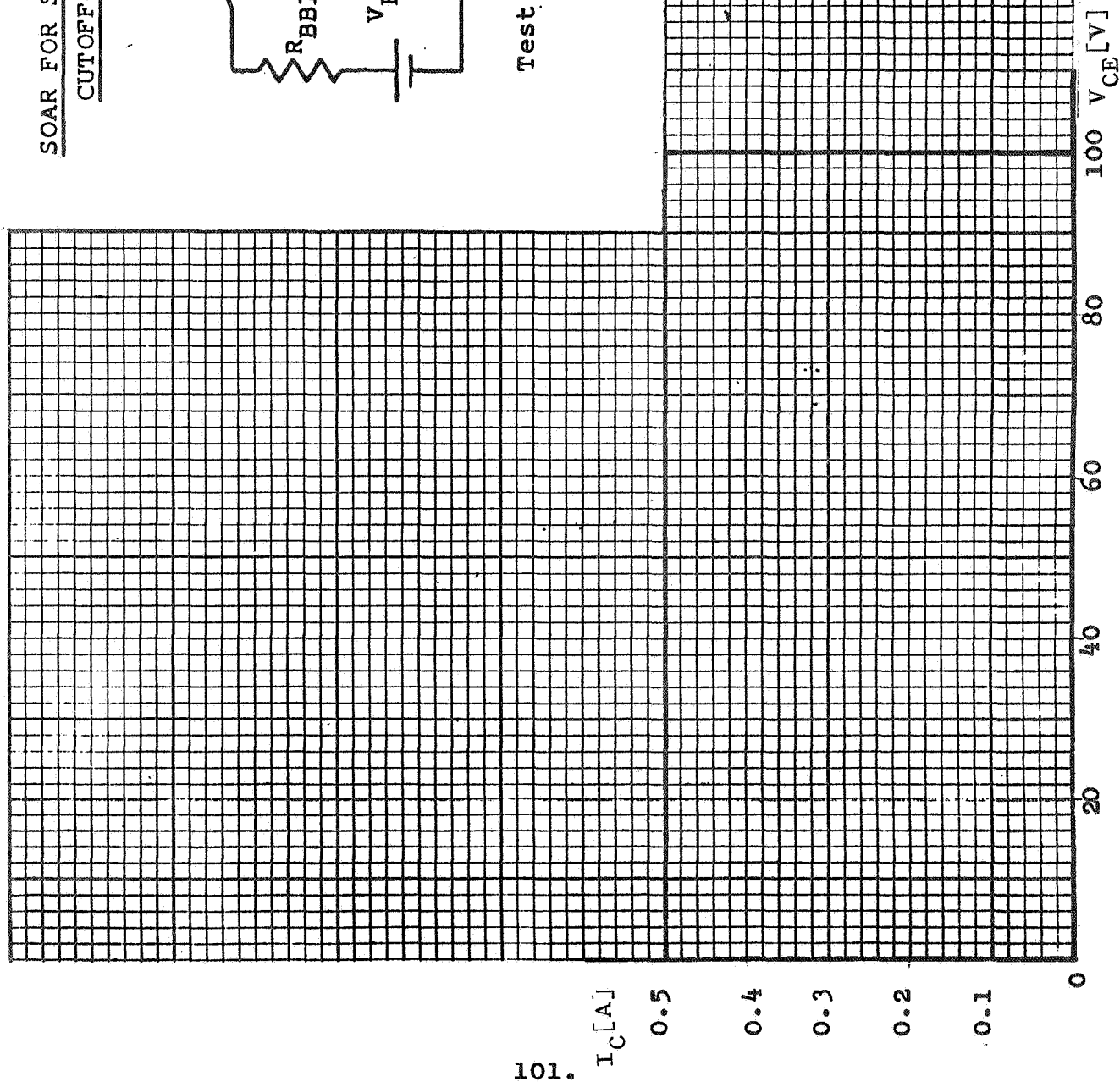
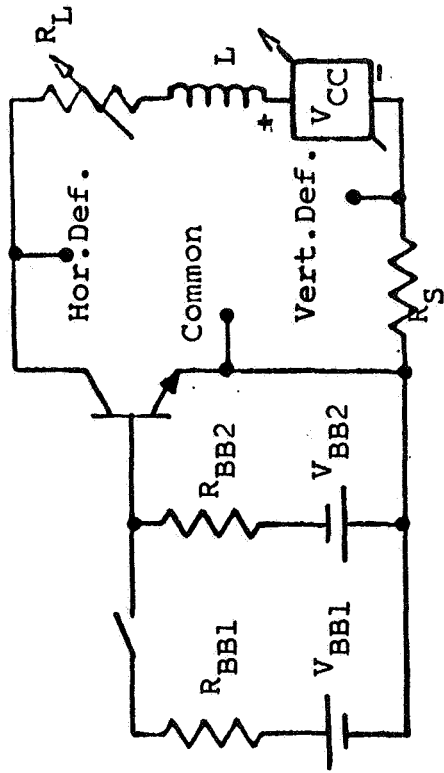


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

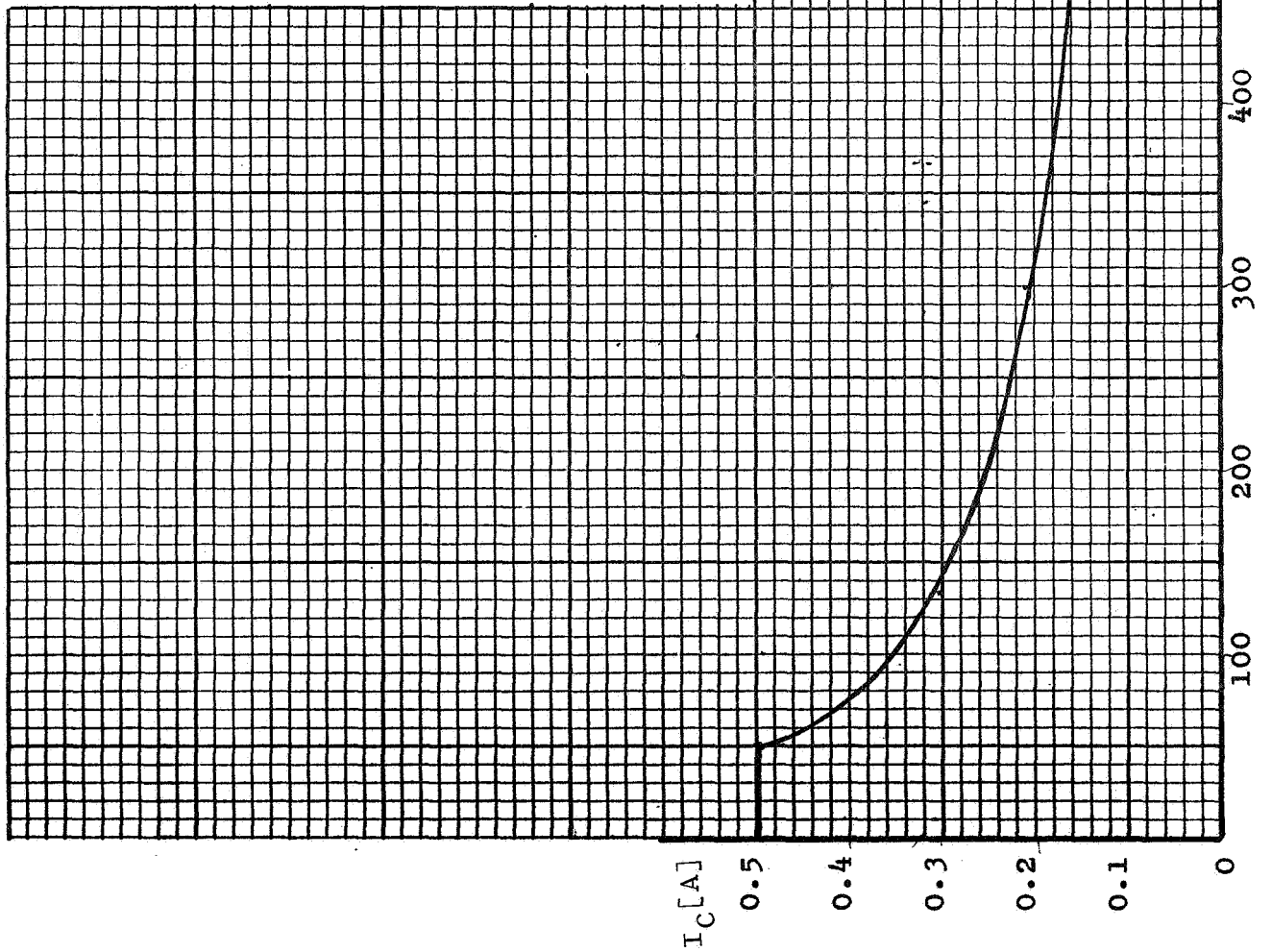


Figure 5

SHORTED CLASS B SOAR

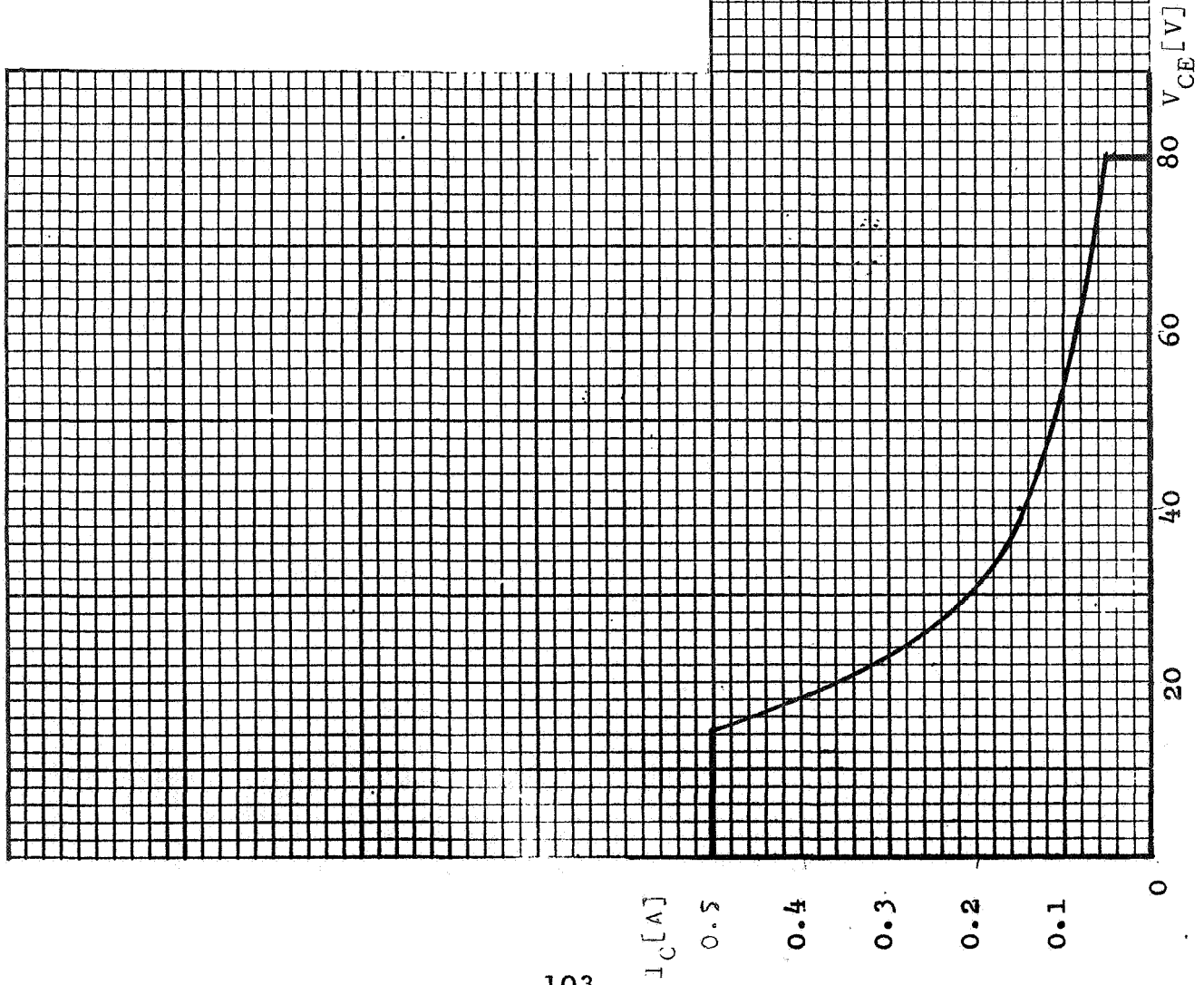
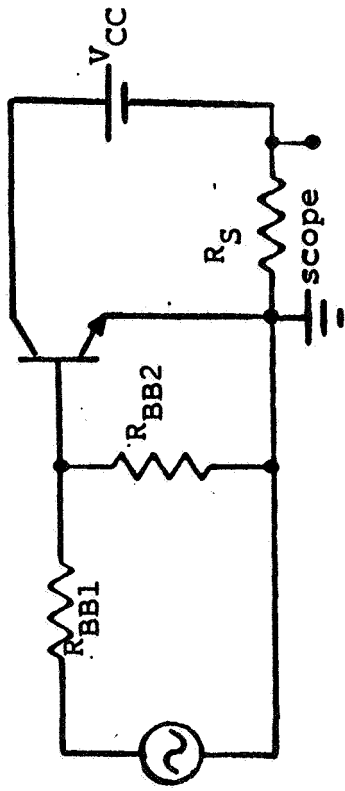


Figure 6

SILICON POWER TRANSISTOR

< Type 2N697 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufactuers E & G --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline - TO-5	
2.2.0	Terminal Designation	
	1 -- Emitter	
	2 -- Base	
	3 -- Collector	
	case -- Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -65^{\circ}C$	JS-6-T1.1 [JEDEC Publication No. 65
	$T_{STG(max)} = 300^{\circ}C$	JS-6-T1.2 "Test Procedures for
		Verification of Maximum
		Ratings of Power Transistors"]
3.1.2	$T_J = 175^{\circ}C$	JS-6-T2
		$T_C = 100^{\circ}C$, $V_{CB} = 40V$, $I_C = 0.025A$
3.1.3	$T(Lead) = 260^{\circ}C$	Distance from case = 1/16 in
		Time 10s
3.2.0	Voltage	$T_C = 25^{\circ}C$
3.2.1	$V_{CBO} = 60V$	JS-6-T3 or MIL-STD-750A, Method 3001.1
3.2.2	$V_{EBO} = 5V$	JS-6-T4 or MIL-STD-750A, Method 3026.1
3.2.3	$V_{CEX} = 40V$	JS-6-T5
		$I_C(V_{CC} = V_{CEX}) = 0.5A$, $V_{CC} = 40V$,
		$R_L = 72\Omega$

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.2.3 V_{CEX} [cont'd]	$L = 10\text{mH} / 0.11\Omega$, [Stancor C-2699] $CR = 1N1204$, $V_{BB1} = 8.5V$, $R_{BB1} = 30\Omega$ $V_{BB2} = 4V$, $R_{BB2} = 65\Omega$, Duty Cycle = $\leq 1\%$
3.3.0 Current	
3.3.1 $I_C = 0.5A$	<u>JS-6-T6</u> $I_B = 0.05A$, $T_C = 25^\circ C$
3.3.2 $I_B = 0.1A$	<u>JS-6-T8</u> $T_C = 25^\circ C$
3.3.3 $I_E = 0.55A$	<u>JS-6-T10</u> $I_B = 0.05A$, $T_C = 25^\circ C$
3.4.0 Power	
3.4.1 $P_T = 1W$	<u>JS-6-T12</u> $T_C = 100^\circ C$, $V_{CB} = 40V$, $I_C = 0.025A$ Derating Factor = $13.3\text{mW}/^\circ C$
3.4.2 $P_{TM} = 20W$	<u>JS-6-T13</u> $T_C = 100^\circ C$, $V_{CC} = 40V$, $I_C = 0.5A$, $V_{BB} = 4V$, $R_{BB} = 65\Omega$, Pulse Width = 0.1m Duty Cycle $\leq 1\%$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC SQAR	<u>JS-6-T12</u> [See Figure 1]

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.5.1 Forward Biased Continuous DC SOAR [cont'd]	$T_C = 100^{\circ}\text{C}$ <u>Test Point:</u> [See 3.4.1]
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> [See Figure 2] <u>Test Point:</u> $T_C = 100^{\circ}\text{C}$, $I_C = 0.5\text{A}$, $R_S = 1\Omega$ $V_{BB} = 4\text{V}$, $R_{BB} = 65\Omega$, $t_r \leq 50\mu\text{s}$, $t_f \leq 50\mu\text{s}$, Duty Cycle $\leq 1\%$ 1. For $t_p = 10\text{ms}$; $V_{CC} = 10\text{V}$ 2. For $t_p = 1\text{ms}$; $V_{CC} = 18\text{V}$ 3. For $t_p = 0.5\text{ms}$; $V_{CC} = 30\text{V}$ 4. For $t_p = 0.1\text{ms}$; $V_{CC} = 40\text{V}$
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<u>JS-6-T5-2.1</u> with L - 0 and CR disconnected [See Figure 3] $T_C = 100^{\circ}\text{C}$ <u>Test Point:</u> $V_{CC} = 60\text{V}$, $I_C = 0.5\text{A}$, $t_r \leq 50\mu\text{s}$, $t_f \leq 50\mu\text{s}$, $R_{BB1} = 30\Omega$, $R_{BB2} = 65\Omega$, $V_{BB1} = 8.5\text{V}$, $V_{BB2} = 4\text{V}$
3.6.2 Clamped Inductive Load	<u>JS-6-T5-2.1</u> [See Figure 4] $T_C = 25^{\circ}\text{C}$ <u>Test Point:</u> [See 3.2.3]

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.3 Unclamped Inductive Load	<p><u>JS-6-T5-2.1</u> and CR disconnected [See Figure 5]</p> <p>$T_C = 25^{\circ}\text{C}$</p> <p><u>Test Point:</u></p> <p>$f = 60\text{Hz}$, Duty Cycle $\leq 1\%$ $R_S = 1\Omega$, $t_r \leq 50\mu\text{s}$, $t_f \leq 50\mu\text{s}$</p> <p>1. $R_{BB1} = 30\Omega$, $R_{BB2} = 65\Omega$, $V_{BB1} = 8.5\text{V}$, $V_{BB2} = 4\text{V}$, $L = 10\text{mH} / 0.11\Omega$, (Stancor C-2688)</p> <p>2. $R_{BB1} = 120\Omega$, $R_{BB2} = 150\Omega$, $V_{BB1} = 5\text{V}$, $V_{BB2} = 2\text{V}$, $I_C = 0.1\text{A}$, $V_{CC} = 14\text{V}$, $R_L = 125\Omega$, $L = 100\text{mH} /$ 1.175Ω, (Series Stancor C-2688 and TRIAD C-47u)</p>
3.7.0 Shorted Class B SOAR	<p>[See Figure 6]</p> <p><u>Test Points:</u></p> <p>$I_{C \text{ peak}} = 0.05\text{A}$, $V_{CC} = 40\text{V}$, $R_S = 10\Omega$, $R_{BB1} = 10\Omega$; $R_{BB2} = 27\Omega$; $f = 20\text{Hz}$, $T_C = 100^{\circ}\text{C}$</p>
4.0.0 <u>Electrical Characteristics</u>	<p>$T_C = 25^{\circ}\text{C}$ [unless otherwise noted]</p>
Maximum Limits unless otherwise noted	

ItemTest Methods and Test Conditions4.0.0 Electrical
Characteristics [Cont'd]

Technique:

DC - Continuous Operation

C.T. - Curve Tracer

P - 300 μ s Pulse, 2% Duty Cycle

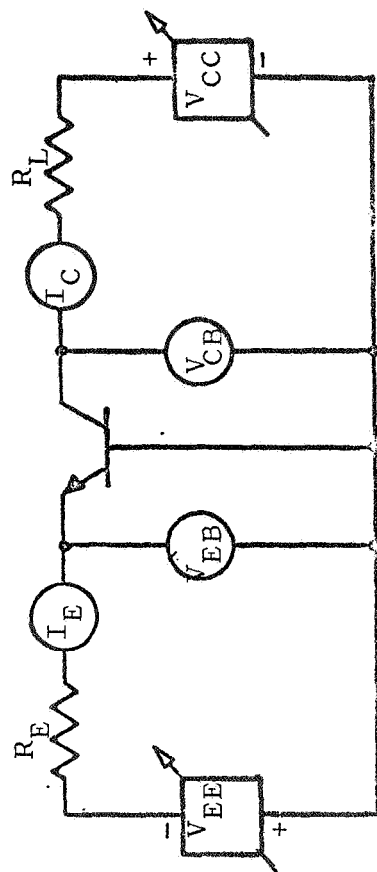
4.1.0 Static

4.1.1	$I_{CEO} = 10\mu A$	$V_{CEO} = 40V$ Technique - C.T.
4.1.2	$I_{CBO} = 1\mu A$	$V_{CBO} = 30V$ Technique - C.T.
4.1.3	$I_{CBO} = 100\mu A$	$V_{CBO} = 30V$, $T_C = 150^\circ C$, Technique-C.T.
4.1.4	$V_{CBO} = 60V$	$I_C = 100\mu A$ Technique - C.T.
4.1.5	$V_{CER} = 40 V$	$I_C = 100\mu A$, $R_B \leq 10\Omega$ Technique-C.T.
4.1.6	$V_{EBO} = 5V$	$I_E = 100\mu A$ Technique - C.T.
4.1.7	$V_{(BR)CEO} = 30V$ min	$I_C = 0.05A$ Technique - C.T.
4.1.8	$h_{FE} = 40$ min 120 max	$V_{CE} = 10V$, $I_C = 0.15A$ Technique - P
4.1.9	$h_{FE} = 25$ min	$V_{CE} = 10V$, $I_C = 0.5A$ Technique - P
4.1.10	$V_{CE(sat)} = 1.5V$	$I_C = 0.15A$, $I_B = 0.015A$, Technique - C.T.
4.1.11	$V_{CE(sat)} = 4V$	$I_C = 0.5A$, $I_B = 0.1A$ Technique - P
4.1.12	$V_{BE(sat)} = 1.3V$	$I_C = 0.15A$, $I_B = 0.015A$ Technique - C.T.
4.1.13	$V_{BE(sat)} = 2.5V$	$I_C = 0.5A$, $I_B = 0.1A$ Technique - P

4.2.0 Dynamic

<u>Item</u>		<u>Test Methods and Test Conditions</u>
4.2.1	$f_T = 50\text{MHz min}$ 160MHz max	$I_C = 0.05\text{A}, V_{CE} = 10\text{V}$ $f = 20\text{MHz}$
4.2.2	$C_{obo} = 35\text{pF}$	$V_{CB} = 10\text{V}, f = 1\text{MHz}$
5.0.0	Thermal Characteristics	
5.1.0	$J(\text{min}) = 70\text{ms}$	$I_C = 0.4\text{A}, V_{CE} = 5\text{V}, \text{MIL-STD-750}$ Method 3146.1
5.2.0	$\Theta_{J-C(\text{max})} = 75^\circ\text{C/W}$	$I_C = 0.4\text{A}, V_{CE} = 5\text{V}, T_C = 20^\circ\text{C}$ MIL-STD-750 Method 3136
5.3.0	$\Theta_{J-A(\text{max})} = 250^\circ\text{C/W}$	

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

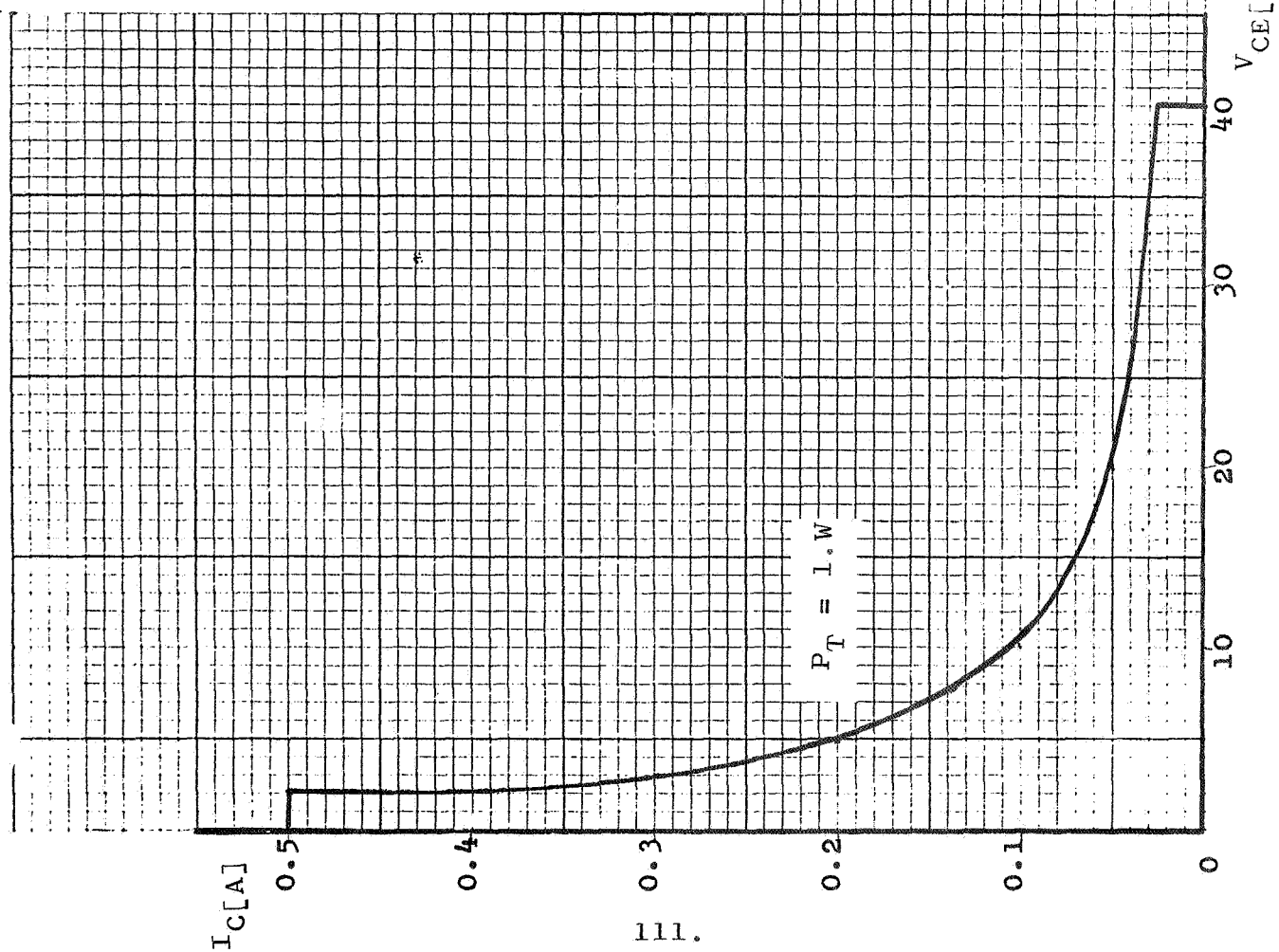
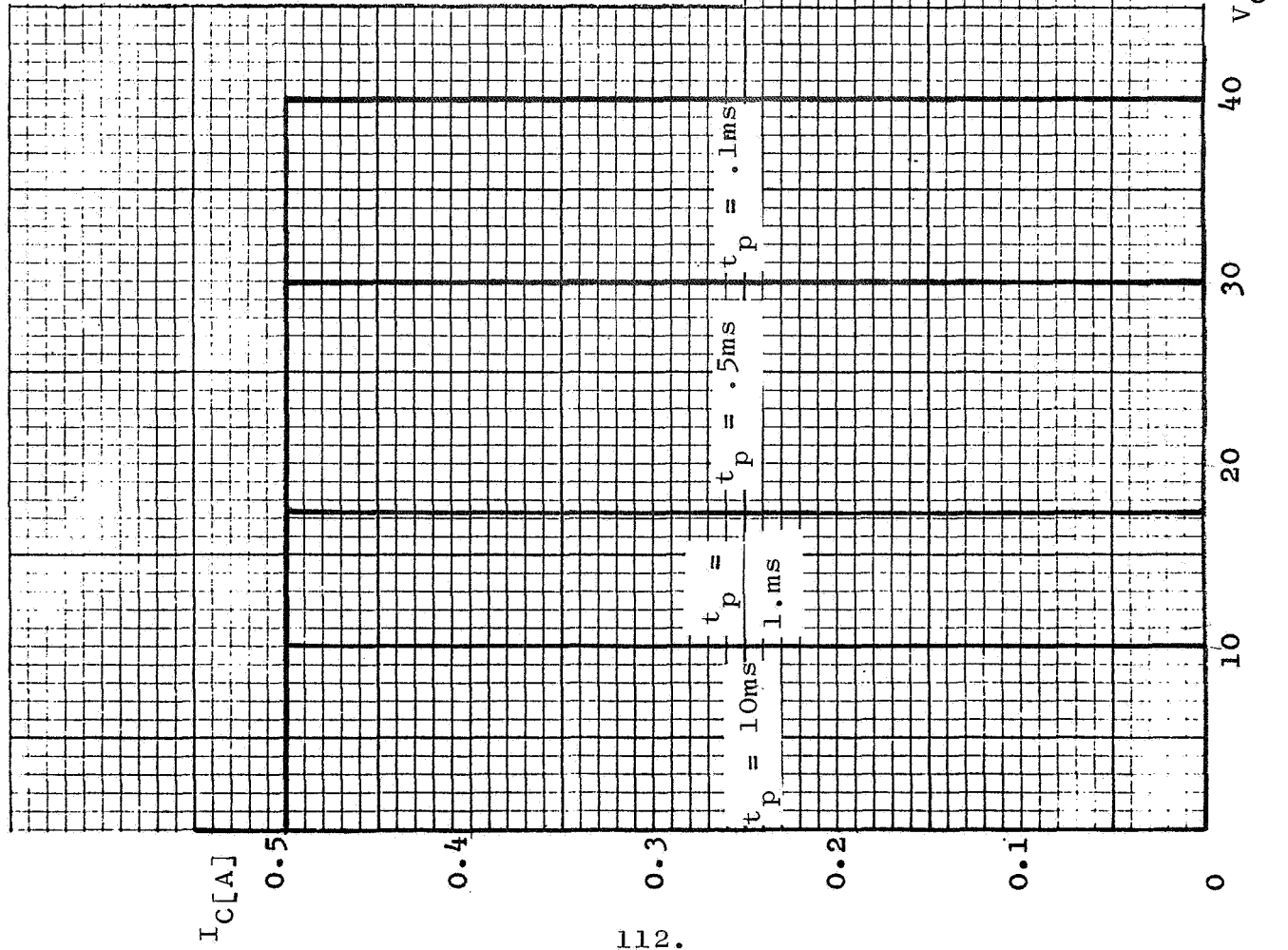
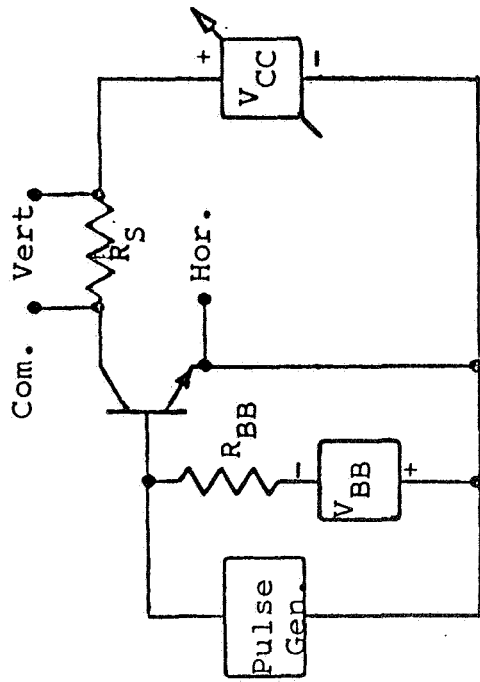


Figure 1



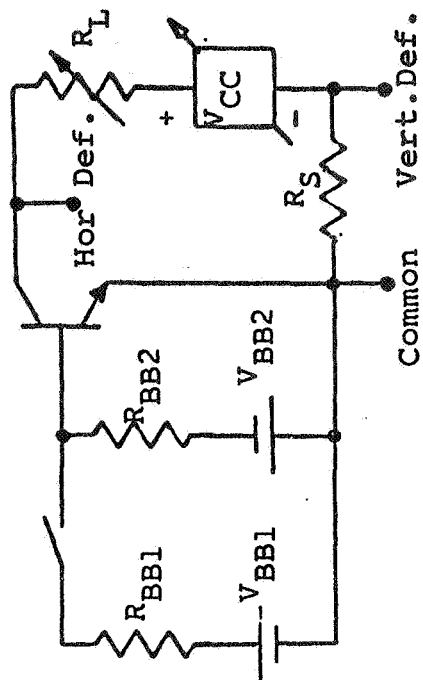
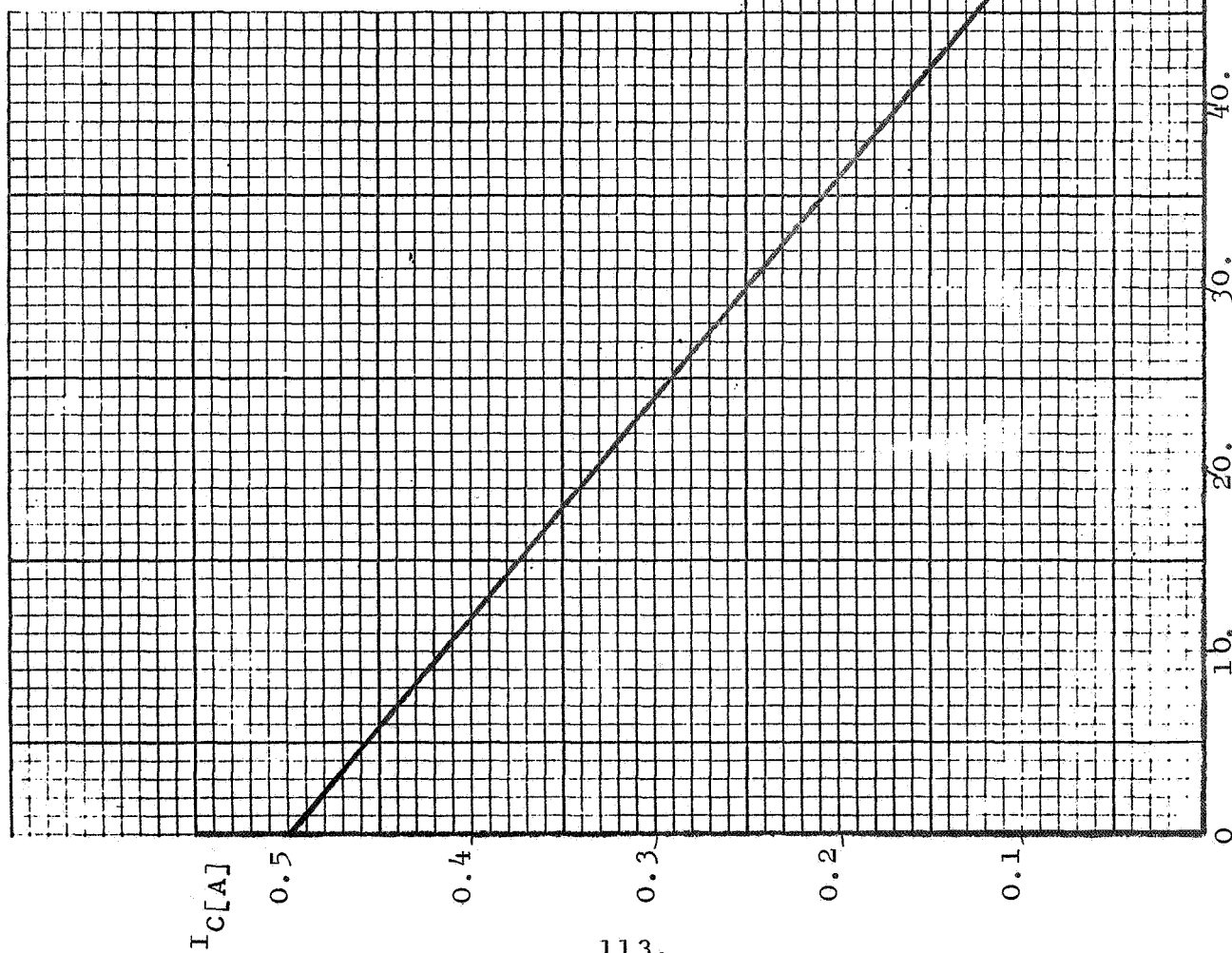
PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

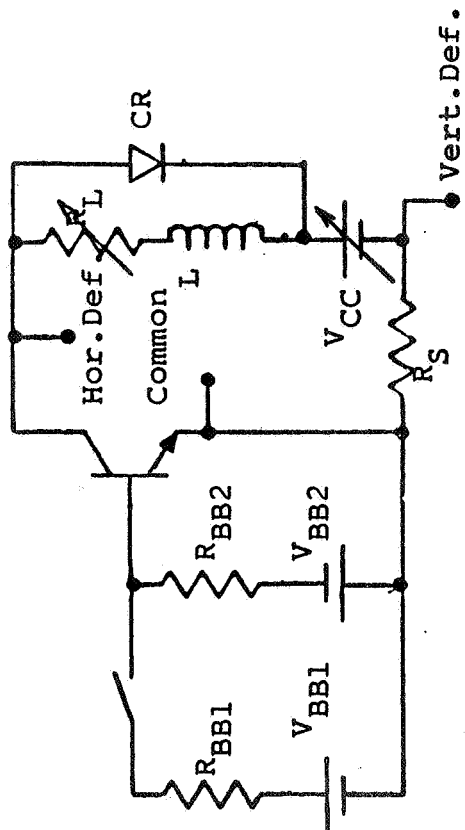


Test Circuit: JS-6-T5.2.1

V_{CE} [V]

Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

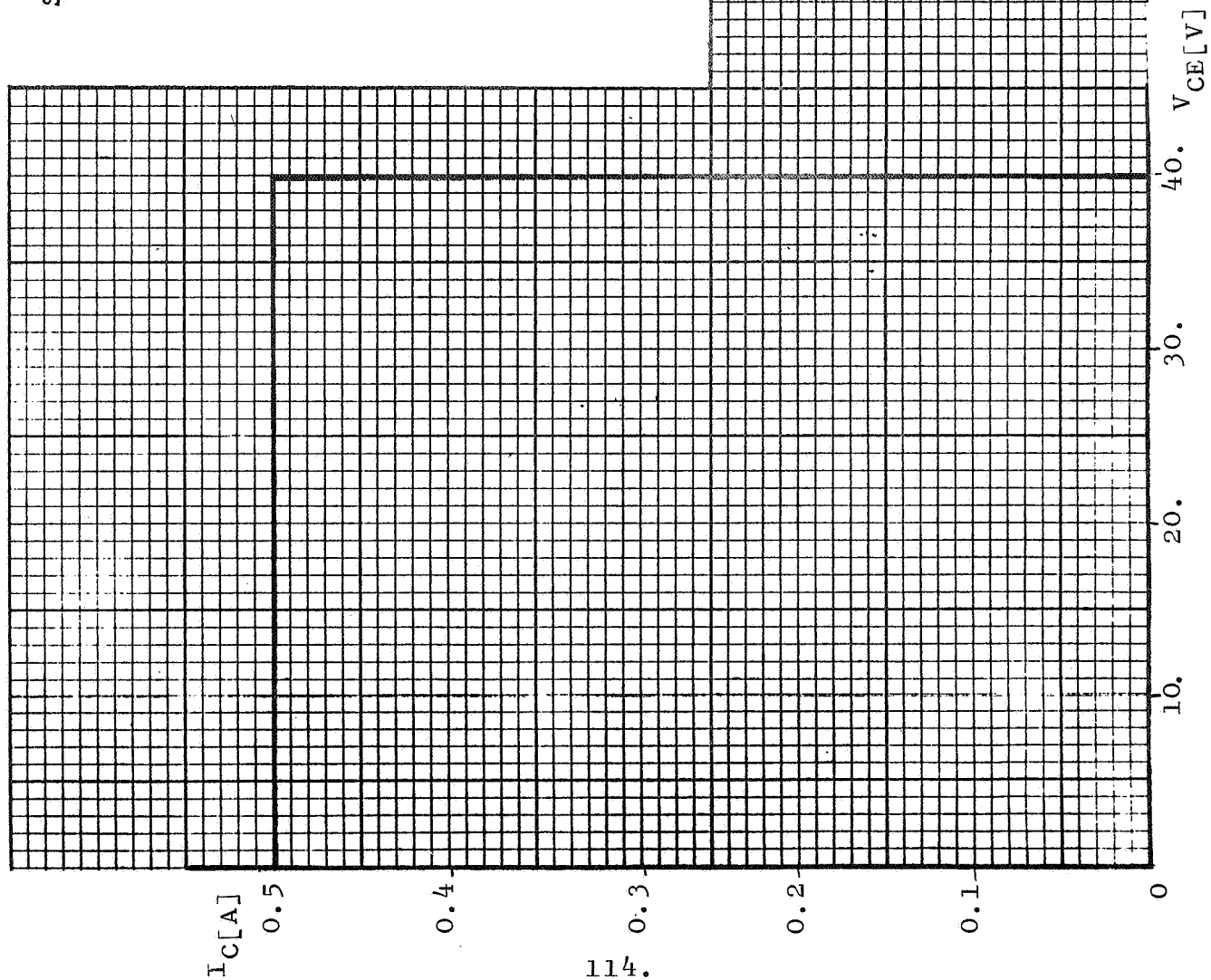
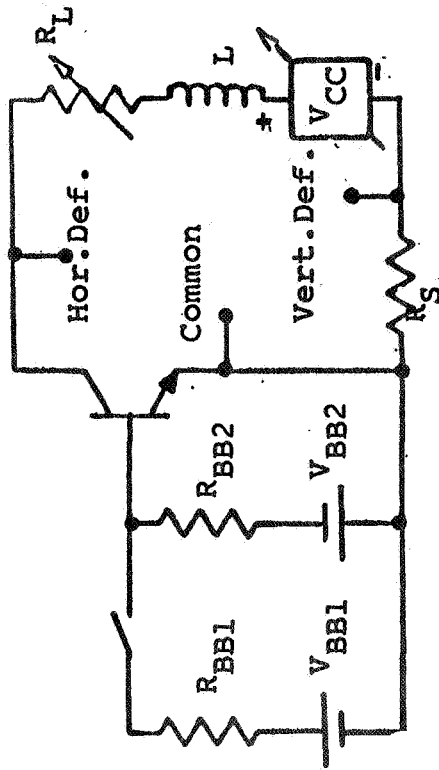


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

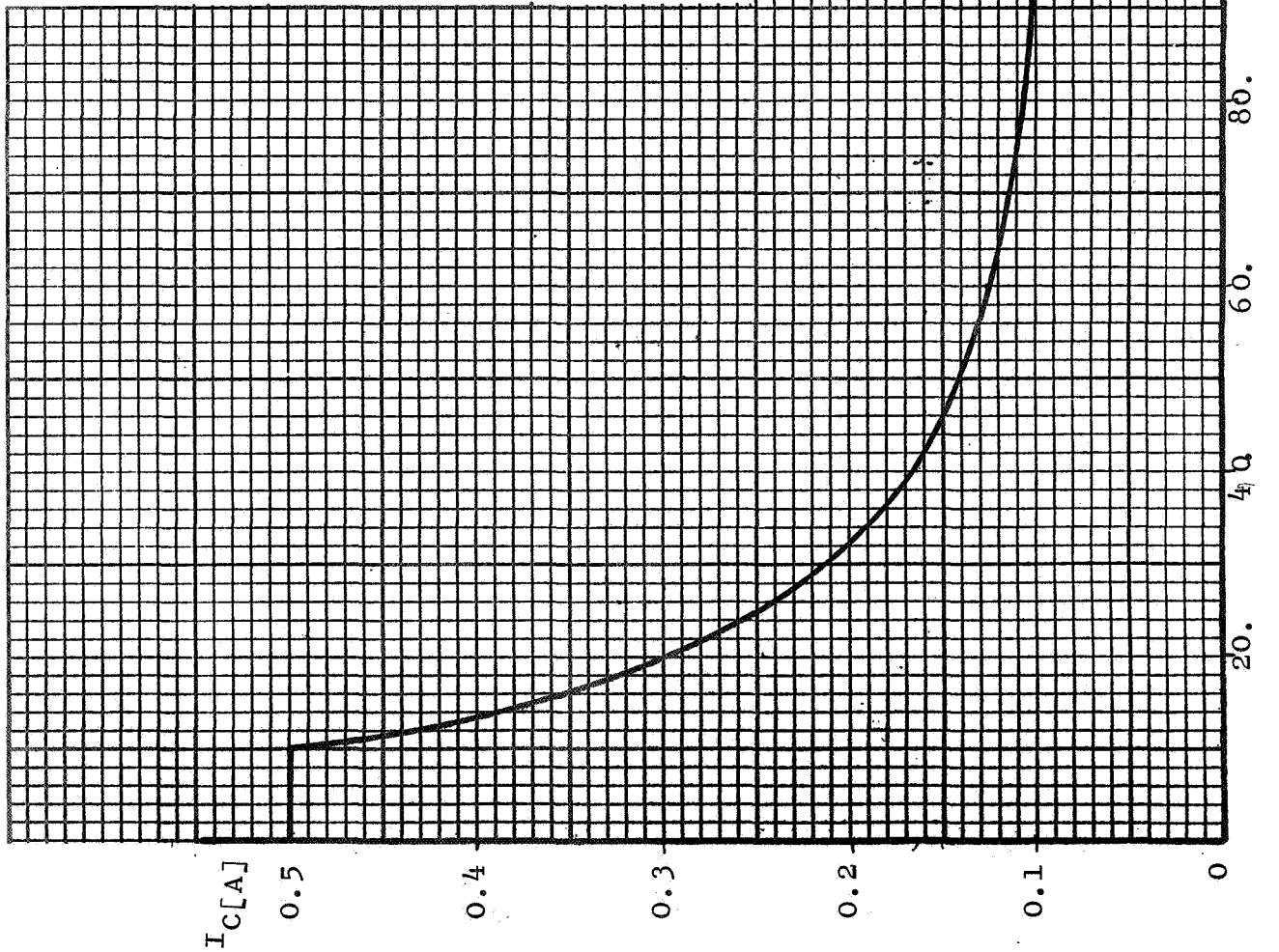


Figure 5

SHORTED CLASS B SOAR

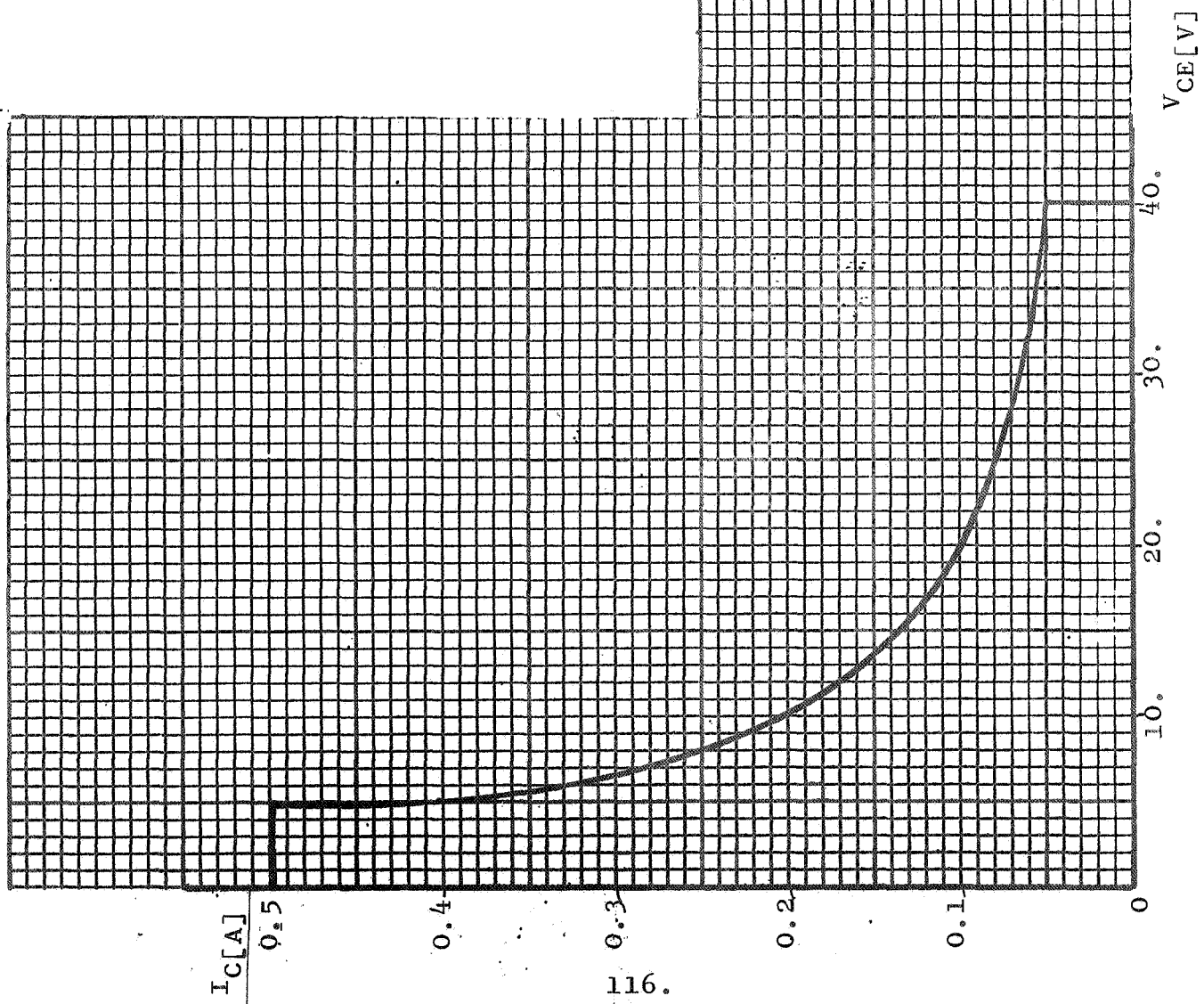
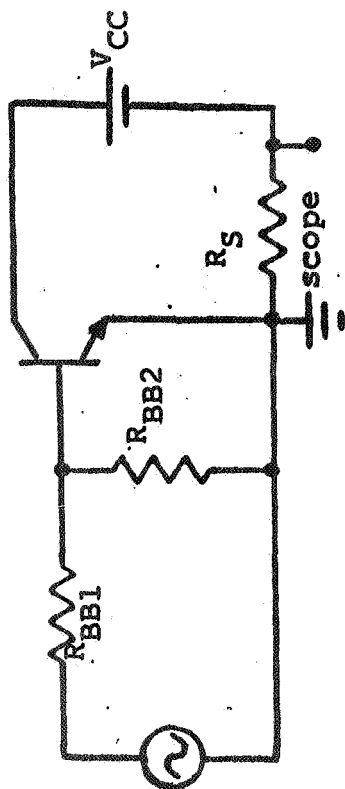


Figure 6

-- TEST REPORT --
SILICON POWER TRANSISTOR
< 2N2880 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item	<u>Test Methods and Test Conditions</u>	
1.0.0	<u>General Description</u>	
1.1.0	Type = NPN	
1.2.0	Material = Silicon	
2.0.0	<u>Mechanical Data</u>	
2.1.0	Outline = TO-111	
2.2.0	Terminal Designation	
	1. --- Emitter	
	2. --- Base	
	3. --- Collector	
	Case - Collector	
3.0.0	<u>Maximum Ratings</u>	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -65^{\circ}C$	<u>JS-6-T1.1</u>
	$T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.2</u>
3.1.2	$T_J(max) = 200^{\circ}C$	<u>JS-6-T2</u>
		$T_C = 100^{\circ}C$
		$P_T = 30W, I_C = 5A$
3.1.3	$T (Lead) = +230^{\circ}C$	Distance from case = 1/16"
		Time = 10 sec.
3.2.0	Voltage	
		$T_C = 25^{\circ}C$
3.2.1	$V_{CB0} = 100V$	<u>JS-6-T3</u> or MIL-STD-750A
		Method 3001.1

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.2.2 $V_{EBO} = 8V$	<u>JS-6-T3</u> or MIL-STD-750A Method 3026.1
3.2.3 $V_{CEX} = 100V$	<u>JS-6-T4</u> or MIL-STD-750A Method 3053 $I_C (V_{CE} = V_{CEX}) = 5A$ $V_{CC} = 100V, R_L = 19.5\Omega$ $L^* = 1.0mH, CR = 1N1204$ $V_{BB1} = 9V, R_{BB1} = 5\Omega$ $V_{BB2} = 2.5V, R_{BB2} = 5\Omega$ Pulse width = 1.0ms, Duty Cycle = 2% $R_S = 0.1\Omega, t_r \leq 50\mu s$ $t_f \leq 50\mu s$ * Miller No. 7871 in series with Miller No. 7825-3
3.3.0 Current	
3.3.1 $I_C = 5A$	<u>JS-6-T6</u> $I_B = 0.5A, T_C \leq 25^\circ C$
3.3.2 $I_B = 0.5A$	<u>JS-6-T8</u> $T_C \leq 25^\circ C$
3.4.0 Power	
3.4.1 $P_T = 30W$	<u>TS-6-T12</u> or MIL-STD-750A Method 3051 $T_C \leq 100^\circ C$ $V_{CB} \approx 30V, I_C = 1A$
Derating Factor= 0.3 W/ $^\circ C$	

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.4.2 $P_{TM} = I_C V_{CC} = 350W$	<u>JS-6-T13</u> or MIL-STD-750A Method 3052 $T_C = 100^{\circ}C$, $V_{CC} = 70V$ $V_{BB} = 2.5V$, $R_{BB} = 5\Omega$ Pulse width = 0.5ms Duty Cycle $\leq 1\%$ $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC SOAR	<u>JS-6-T12</u> or MIL-STD-750A Method 3051 [see figure 1] <u>Test Points:</u> 1. [see 3.4.1] 2. $V_{CB} \approx 70V$, $I_C = 0.2A$, $T_C = 100^{\circ}C$, $P_T = 14W$
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T1.4</u> or MIL-STD-750A Method 3052 Test Points: [see figure 2] $T_C \leq 100^{\circ}C$, $V_{BB} = 2.5V$ $R_{BB} = 5\Omega$, $I_C = 5A$ $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Duty Cycle $\leq 1\%$, $R_S = 0.1\Omega$ 1. For $t_p = 5ms$; $V_{CC} = 20V$ 2. For $t_p = 2.5ms$; $V_{CC} = 35V$ 3. For $t_p = 1ms$; $V_{CC} = 50V$ 4. For $t_p = 0.5ms$; $V_{CC} = 70V$

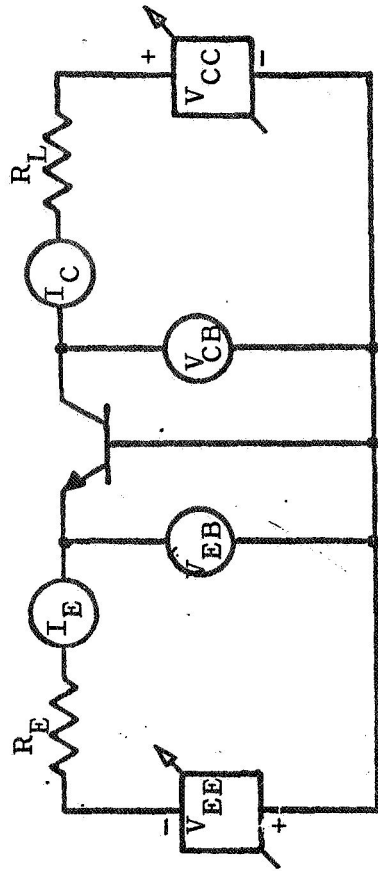
<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<u>JS-6-T5.1</u> or MIL-STD-750A Method 3053 with $L = 0$ and CR disconnected [see figure 3] <u>Test Points:</u> $I_C = 5A$, $V_{CC} = 100V$, $R_{BB1} = 5\Omega$ $R_{BB2} = 5\Omega$, $V_{BB1} = 9V$, $V_{BB2} = 2.5V$ $T_C = 100^\circ C$; $R_S = 0.1\Omega$ $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Collector Current
3.6.2 Clamped Inductive Load	<u>JS-6-T5.1</u> or MIL-STD-750A Method 3053 [see figure 4] <u>Test Points:</u> $I_C = 5A$, $V_{CC} = 100V$, $R_L = 19.5\Omega$ $L = 1mH$, $R_{BB1} = 5\Omega$, $R_{BB2} = 5\Omega$ $V_{BB1} = 9V$, $V_{BB2} = 2.5V$, $t_p = 1ms$, CR = 1N1204, $T_C = 25^\circ C$, $t_r \leq 50\mu s$ $t_f \leq 50\mu s$, Duty Cycle = 2% $R_S = 0.1\Omega$
3.6.3 Unclamped Inductive Load	<u>JS-6-T5.1</u> or MIL-STD-750A Method 3053 with CR disconnected <u>Test Points:</u> [see figure 5] $R_{BB1} = 5\Omega$, $R_{BB2} = 5\Omega$, $R_S = 0.1\Omega$ $V_{BB1} = 9V$, $V_{BB2} = 2.5V$, $f = 20Hz$

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.6.3 [Cont'd]	$T_C = 25^{\circ}\text{C}$ 1. $I_C = 4\text{A}$, $V_{CC} = 30\text{V}$, $R_L = 7\Omega$ $L = 125\mu\text{H}$ - Two Miller 7825-3 in parallel 2. $I_C = 0.5\text{A}$, $V_{CC} = 10\text{V}$, $R_L = 19\Omega$ $L = 10\text{mH}$ - Stancor C-2688
3.7.0 Shorted Class B SOAR	[see figure 6] <u>Test Points:</u> $I_C (\text{peak}) = 0.3\text{A}$, $V_{CC} = 70\text{V}$, $R_S = 0.1\Omega$, $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20\text{Hz}$, $T_C = 100^{\circ}\text{C}$
4.0.0 <u>Electrical Characteristics</u>	
Maximum limits unless otherwise noted.	$T_C = 25^{\circ}\text{C}$ [unless otherwise noted]
Techniques:	
DC = Continuous Operation	
C.T. = Curve Tracer	
P = 300 μs Pulse	
2% Duty Cycle	
4.1.0 Static	
4.1.1 $I_{CEX} = 50\mu\text{A}$	$V_{CE} = 60\text{V}$, $V_{BE} = -0.5\text{V}$, $T_C = 150^{\circ}\text{C}$, Techniques - C.T.

<u>Item</u>	<u>Test Methods and Test Conditions</u>
4.1.2 $I_{CEX} = 10\mu A$	$V_{CE} = 100V, V_{BE} = -0.5V$ Technique - C.T.
4.1.3 $I_{CBO} = 50\mu A$	$V_{CB} = 60V, T_C = 150^{\circ}C$ Technique - C.T.
4.1.4 $I_{CBO} = 0.1\mu A$	$V_{CB} = 60V$ Technique - C.T.
4.1.5 $I_{EBO} = 10\mu A$	$V_{EB} = 8V$ Technique - C.T.
4.1.6 $I_{EBO} = 0.1\mu A$	$V_{EB} = 5V$ Technique - C.T.
4.1.7 $V_{(BR)CEO} = 80V \text{ min}$	$I_C = 10mA$ Technique - C.T.
4.1.8 $V_{(BR)CEO} = 70V \text{ min}$	$I_C = 0.1A$ Technique - C.T.
4.1.9 $I_{CEO} = 100\mu A$	$V_{CEO} = 50V$ Technique - C.T.
4.1.10 $h_{FE} = 30 \text{ min}$ 120 max	$V_{CE} = 2V, I_C = 10mA$ Technique - P
4.1.11 $h_{FE} = 40 \text{ min}$ 120 max	$V_{CE} = 2V, I_C = 1A$ Technique - P
4.1.12 $h_{FE} = 15 \text{ min}$ 60 max	$V_{CE} = 2V, I_C = 1A, T_C = -55^{\circ}C$ Technique - P
4.1.13 $h_{FE} = 60 \text{ min}$ 200 max	$V_{CE} = 2V, I_C = 1A, T_C = 150^{\circ}C$ Technique - P
4.1.14 $h_{FE} = 15 \text{ min}$ 45 max	$V_{CE} = 5V, I_C = 5A$ Technique - P

<u>Item</u>	<u>Test Methods and Test Conditions</u>
4.1.15 $V_{CE(sat)} = 0.25V \text{ max}$	$I_C = 1A, I_B = 0.1A$ Technique - C.T.
4.1.16 $V_{CE(sat)} = 2.0V \text{ max}$	$I_C = 5A, I_B = 0.5A$ Technique - C.T.
4.1.17 $V_{BE(sat)} = 1.2V \text{ max}$	$I_C = 1A, I_B = 0.1A$ Technique - C.T.
4.1.18 $V_{BE(sat)} = 2V \text{ max}$	$I_C = 5A, I_B = 0.5A$ Technique - C.T.
4.1.19 $V_{BE} = 1.2V \text{ max}$	$V_{CE} = 2V, I_C = 1A$ Technique - C.T.
4.2.0 Dynamic	
4.2.1 $t_{ON} = 300ns$	$V_{CC} = 20V, I_C = 1A$
4.2.2 $t_{OFF} = 2.0\mu s$	$I_{B1} = - I_{B2} = 100mA$
4.2.3 $\left h_{FE} \right = 2 \text{ min}$ $= 9 \text{ max}$	$V_{CE} = 10V, I_C = 1A, f = 10MHz$
4.2.4 $C_{obo} = 150 \text{ pF max}$	$V_{CB} = 10V, f = 1MHz$
5.0.0 <u>Thermal</u> <u>Characteristics</u>	
5.1.0 $\tau_J = 5ms \text{ min}$	MIL-STD-750, method 3146.1 $V_{CE} = 10V, I_C = 2A, T_C = 25^\circ C$
5.2.0 $\theta_{J-C} = 3.33^\circ C/W$	MIL-STD-750A, method 3136 $V_{CE} = 5V, I_C = 2A$

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ C$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

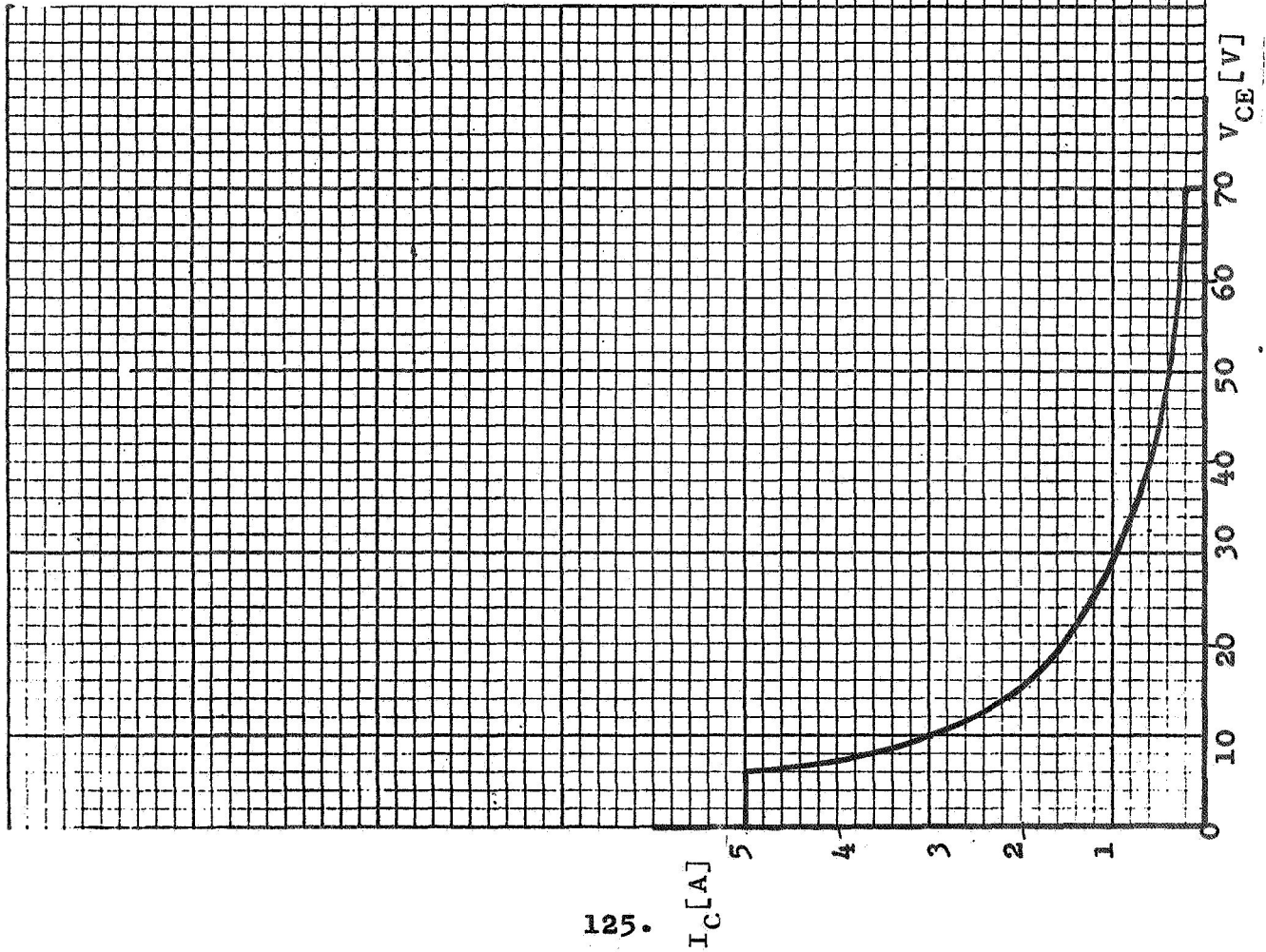
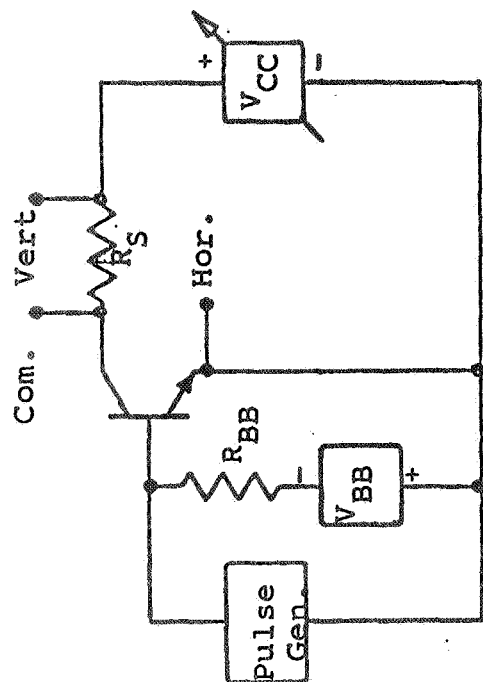


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

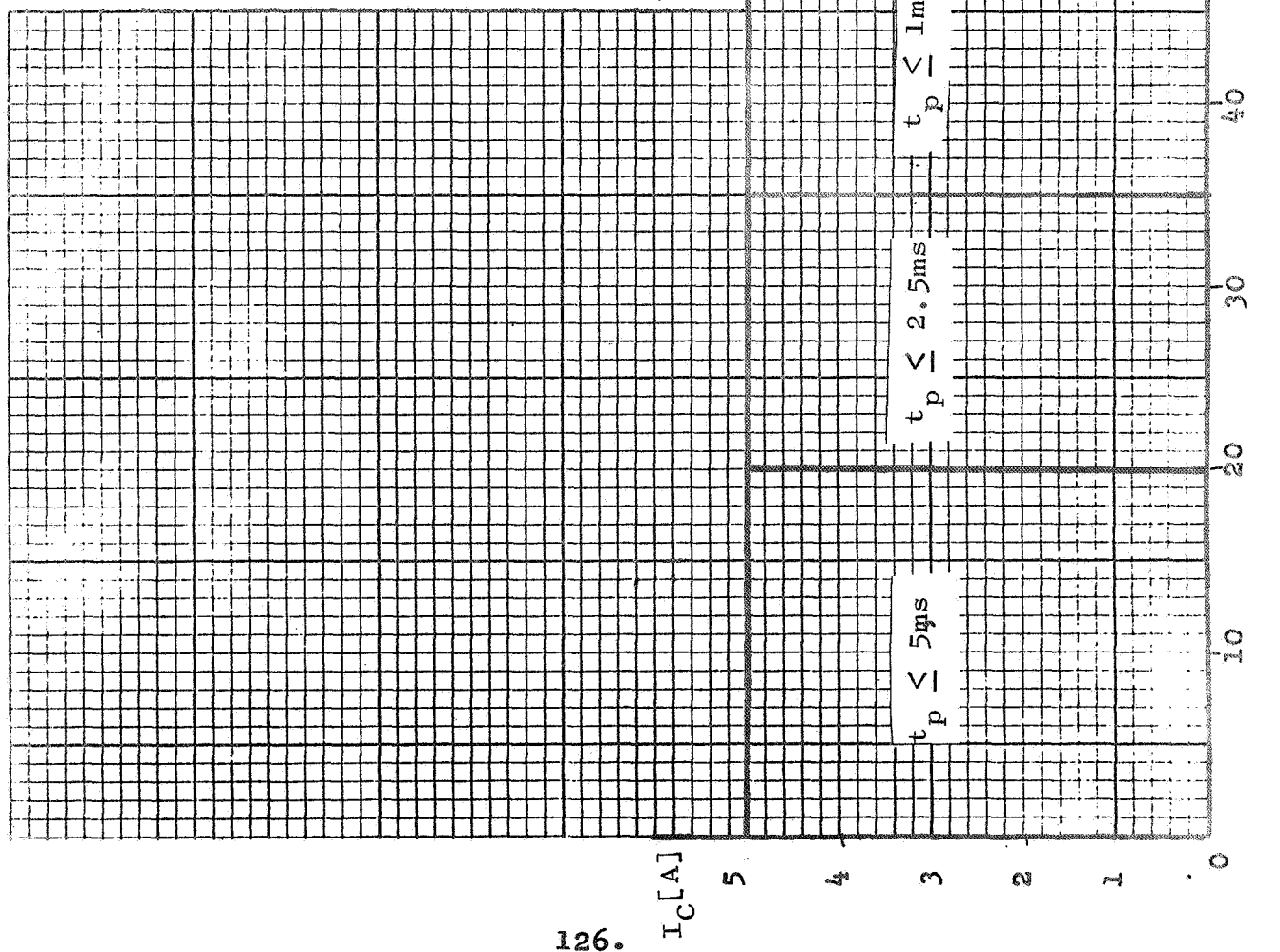


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

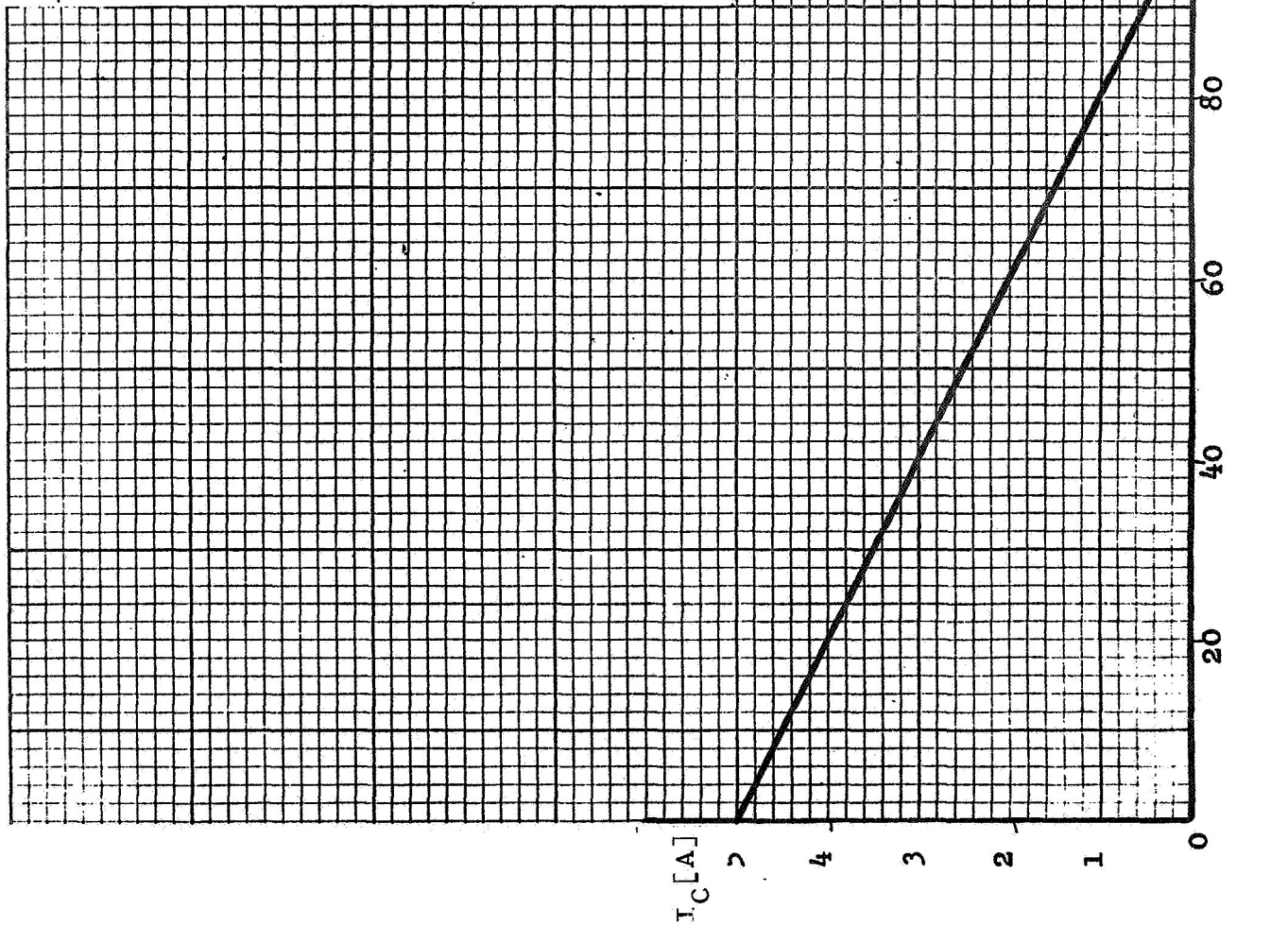
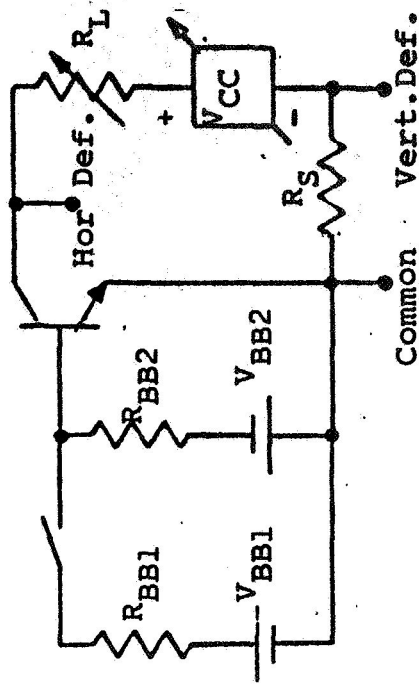
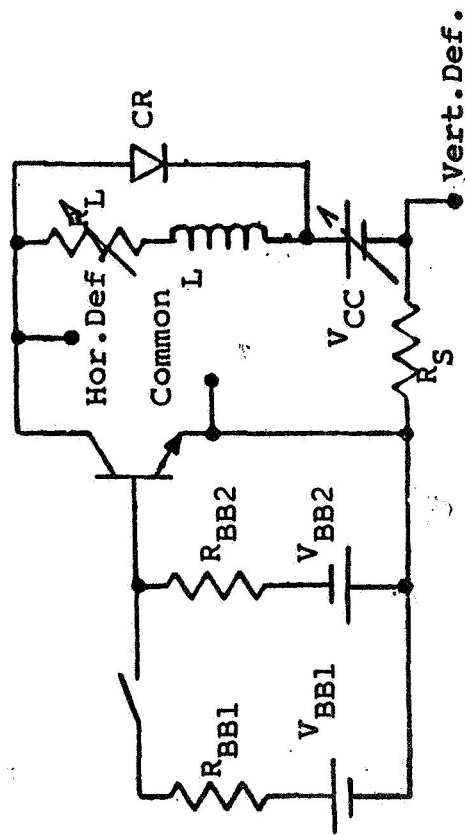


Figure 3

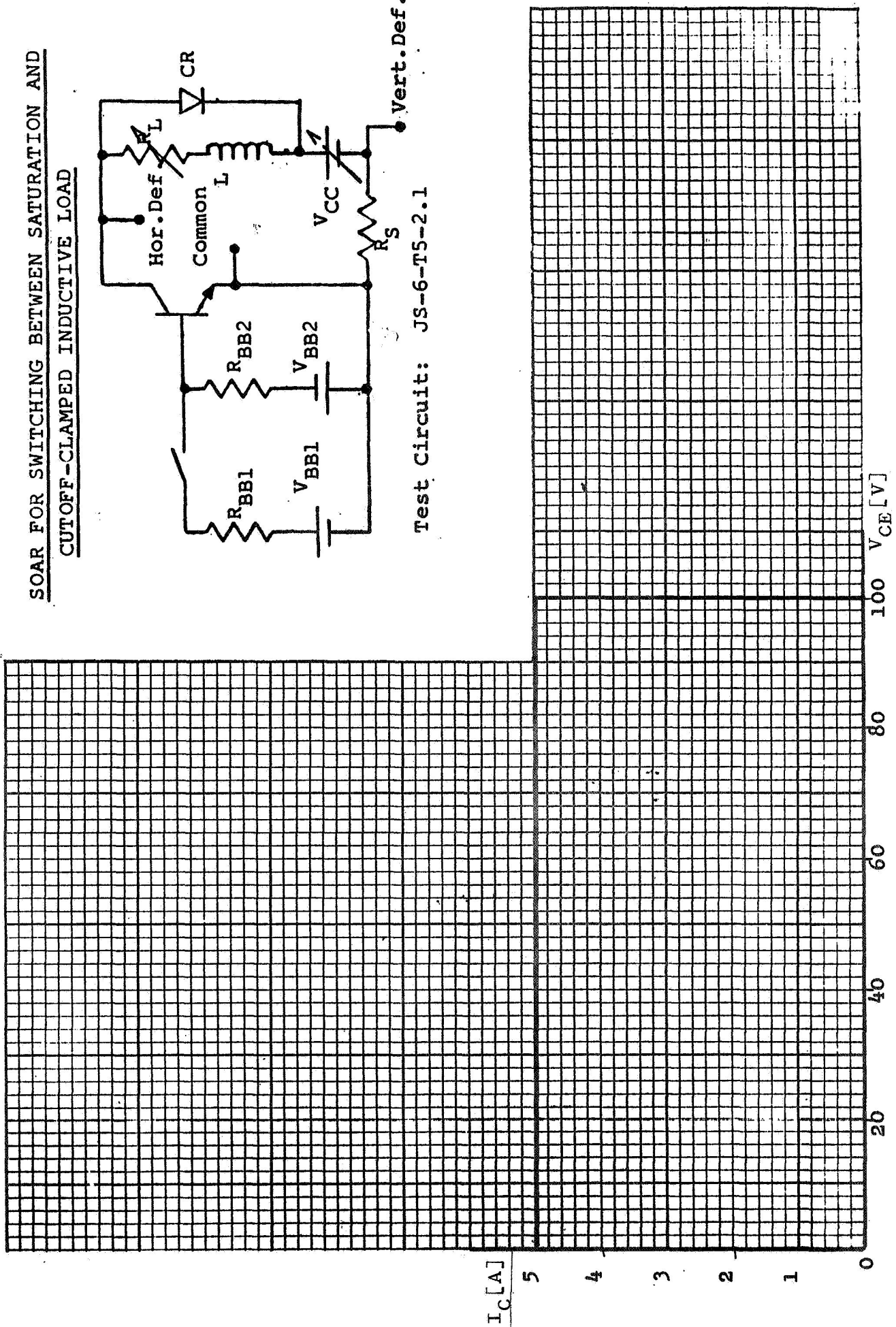


Test Circuit: JS-6-T5.2.1

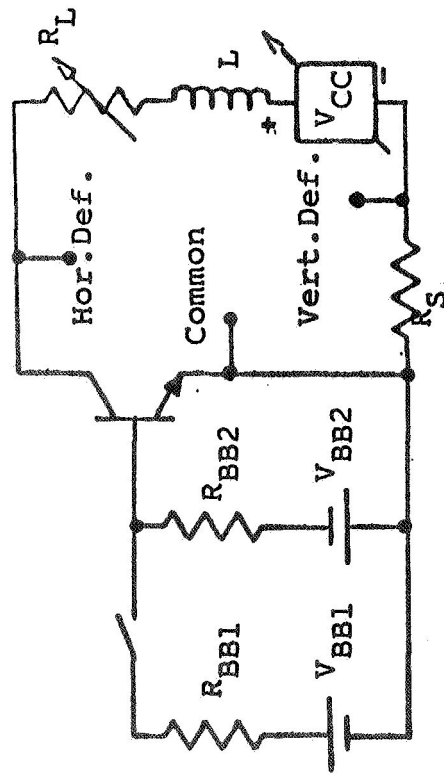
SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1



SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

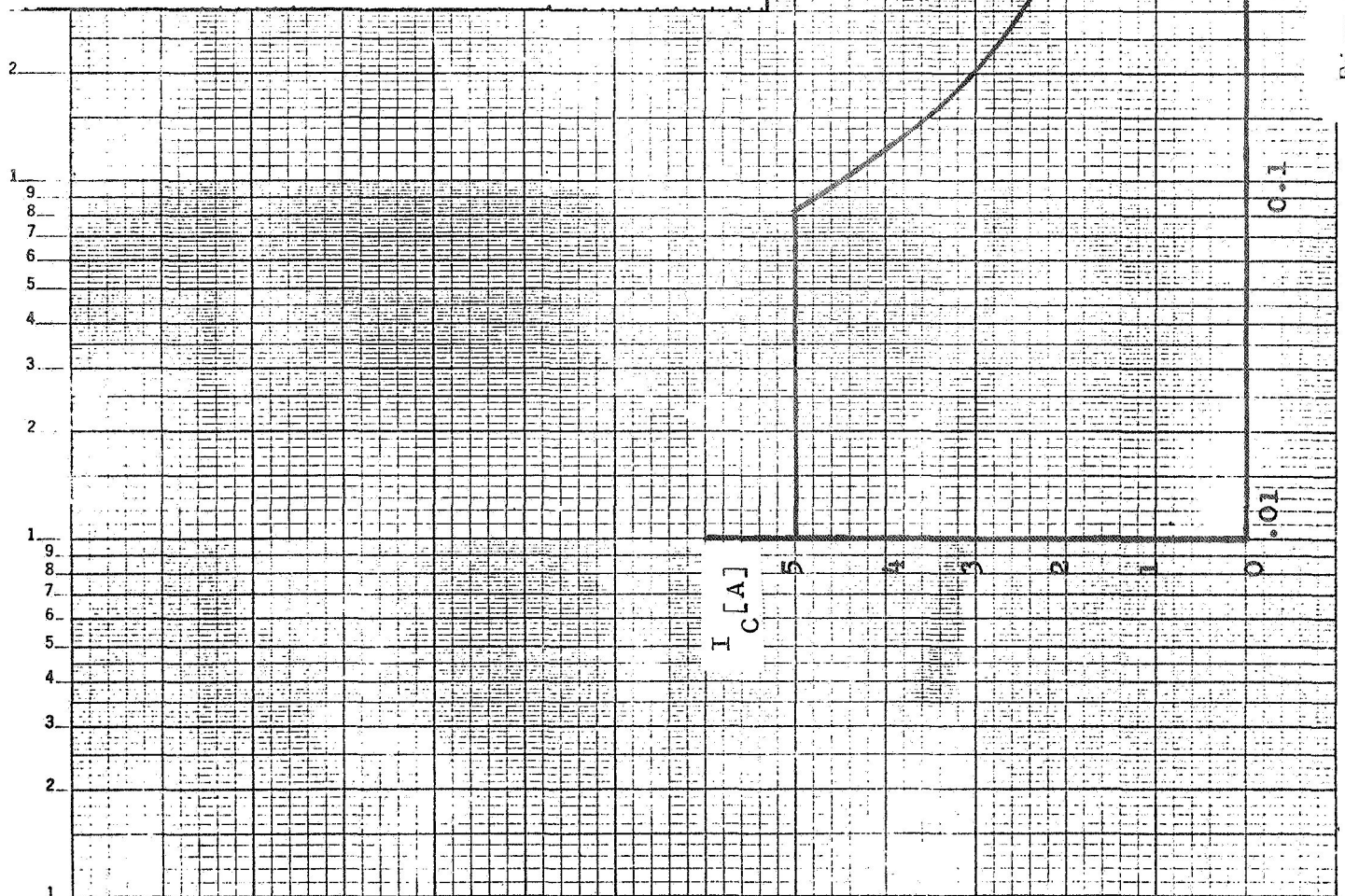


Figure 5

SHORTED CLASS B SOAR

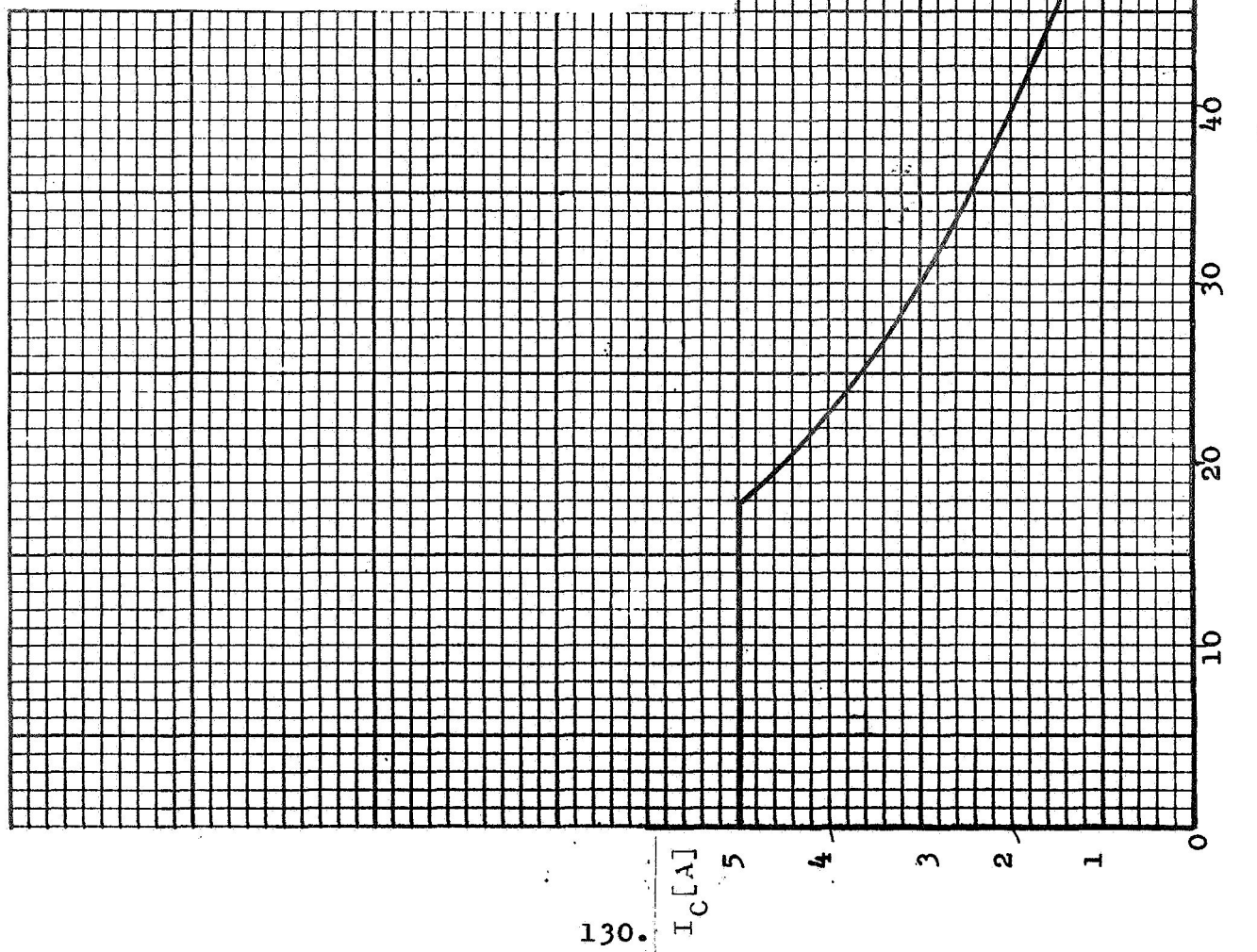
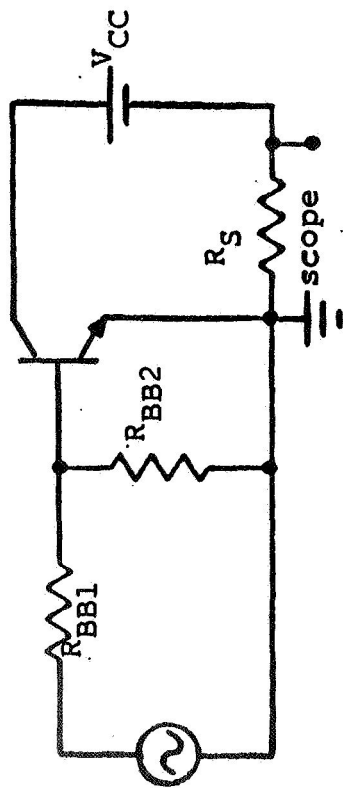


Figure 6

-- TEST REPORT --

SILICON POWER TRANSISTOR

< S2N4150 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

<u>Item</u>	<u>Test Methods and Test Condition</u>
1.0.0 <u>General Description</u>	
1.1.0 Type -- NPN	
1.2.0 Material -- Silicon	
2.0.0 <u>Mechanical Data</u>	
2.1.0 Outline T0-5	
2.2.0 Terminal Designation	
1 --- Base	
2 --- Emitter	
3 --- Collector	
Case--Collector	
3.0.0 <u>Maximum Ratings</u>	
3.1.0 Temperature	
3.1.1 $T_{STG(min)} = -55^{\circ}C$	<u>JS-6-T1.1</u> [JEDEC Suggested standard:
$T_{STG(max)} = +200^{\circ}C$	<u>JS-6-T1.2</u> "Test Procedure for
	Verification of Maximum
	Ratings." JEDEC Publication
	No. 65.]
3.1.2 $T_{J(max)} = +200^{\circ}C$	<u>JS-6-T2</u> or MIL-STD-750A Method 3051
	$T_C = 100^{\circ}C$, $P_T = 5W$, $I_C = 0.1A$,
	$V_{CE} = 50V$
3.1.3 T (Lead) = $230^{\circ}C$	Distance from Case 1/16"
	Time = 3 sec.
3.2.0 Voltage	

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.2.1 $V_{(BR)CBO} = 120V$	<u>JS-6-T3</u> or MIL-STD-750A Method 3001.1
3.2.2 $V_{(BR)EBO} = 7V$	<u>JS-6-T4</u> or MIL-STD-750A Method 3026.1
3.2.3 $V_{(BR)CEX} = 70V$	<u>JS-6-T5.1</u> or MIL-STD-750A Method 3053 $I_C \leq 10A$, $V_{CE} = 70V$, $R_{BB1} = 10\Omega$, $R_{BB2} = 20\Omega$. $V_{BB1} = 16V$, $V_{BB2} = 5.0V$ $R_L = 7\Omega$, $L^* = 1.0mH$ $R_S = 0.1\Omega$ $t_r \leq 10\mu s$, $t_f \leq 10\mu s$, $t_p = 300\mu s$ Duty cycle $\leq 0.2\%$ *J.W. Miller: 7871 in series with 7825-3
3.3.0 Current	
3.3.1 $I_C = 3.0A$	<u>JS-6-T-6</u> $I_B = 0.3A$, $T_C = 25^\circ C$
3.3.2 $I_{CM} = 10A$	<u>JS-6-T7</u> $T_C = 25^\circ C$ $R_S = 0.1\Omega$ $V_{BB} = 5V$ $R_{BB} = 20\Omega$ $I_B = 1A$, $t_p = 300\mu s$ $d \leq 0.2\%$ $t_r \leq 10\mu s$, $t_f \leq 10\mu s$
3.3.3 $I_B = 0.5A$	<u>JS-6-T8</u> $T_C = 25^\circ C$

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.3.4 $I_{BM} = 1.0A$	<u>JS-6-T4</u> $T_C = 25^{\circ}C$, $R_S = 1.0\Omega$, $t_p = 300\mu s$, $t_r \leq 10\mu s$ $t_f \leq 10\mu s$, $d \leq 0.2\%$
3.3.5 $I_E = 3.3A$	<u>JS-6-T10</u> $I_B = 0.3A$, $T_C = 25^{\circ}C$ [see 3.3.2]
3.3.6 $I_{EM} = 11A$	
3.4.0 Power	
3.4.1 $P_T = 5.0W$	<u>JS-6-T12</u> <u>Test Point:</u> [See 3.1.2]
3.4.2 $P_{TM} = I_C V_{CC} = 700W$	<u>JS-6-T13</u> or MIL-STD-750A Method 3052 $T_C = 100^{\circ}C$, $V_{CC} = 70V$, $V_{BB1} = 16V$, $R_{BB} = 10\Omega$, $I_C = 10A$, Pulse Width = $100\mu s$ Duty Cycle $\leq 0.2\%$ $t_r \leq 10\mu s$ $t_f \leq 10\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	<u>JS-6-T12</u> or MIL-STD-750A Method 3051 Test Points: [See 3.1.2]

<u>Item</u>	<u>Test Methods and Test Conditions</u>
3.5.2 Pulsed Forward Biased SOAR	<u>JS-6-T14</u> or MIL-STD-750A Method 3052 <u>Test Points:</u> $T_C = 100^{\circ}\text{C}$, $V_{BB} = 5\text{V}$, $R_{BB} = 20\Omega$, $t_r \leq 10\mu\text{s}$, $t_f \leq 10\mu\text{s}$, $I_C = 10\text{A}$, Duty Cycle $\leq 0.2\%$, $R_S = 0.1\Omega$, 1. $t_p = 100\mu\text{s}$: $V_{CC} = 70\text{V}$ 2. $t_p = 200\mu\text{s}$: $V_{CC} = 50\text{V}$ 3. $t_p = 300\mu\text{s}$: $V_{CC} = 30\text{V}$
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	<u>JS-6-T5-5.1</u> or MIL-STD-750A Method 3053 with $L = 0$ and CR disconnected <u>Test Points:</u> $R_{BB1} = 10\Omega$, $R_{BB2} = 20\Omega$, $V_{BB1} = 16\text{V}$, $V_{BB2} = 5.0\text{V}$, $T_C = 100^{\circ}\text{C}$, $t_f \leq 10\mu\text{s}$, $t_r \leq 10\mu\text{s}$, $R_S = 0.1\Omega$, $R_L = 12\Omega$, $V_{CC} = 120$, $d \leq 0.2\%$, $t_p \leq 300\mu\text{s}$
3.6.2 Clamped Inductive Load	<u>JS-6-T5.1</u> or MIL-STD-750A Method 3053 Test Point: [see 3.2.3]

ItemTest Methods and Test Conditions3.6.3 Unclamped
Inductive LoadJS-6-T5.1 or MIL-STD-750A

Method 3053 and CR disconnected

Test Points:

1. $V_{BB1} = 16V$ $L^* = 1.0mH$
 $R_{BB1} = 10\Omega$ $R_L = .35\Omega$
 $V_{BB2} = 5.0V$ $V_{CC} = \text{adjust to}$
 $I_C = 10A$
 $R_{BB2} = 20\Omega$ $t_p = 300\mu s$
 $R_S = 0.1\Omega$ $d \leq 0.2\%$

*J.W.Miller:7871 in series with 7825-3

2. $V_{BB1} = 6.0V$ $L^* = 10mH$
 $R_{BB1} = 10\Omega$ $R_L = .11\Omega$
 $V_{BB2} = 5.0V$ $V_{CC} = \text{adjust to}$
 $d \leq 0.2\%$ $I_C = 0.5A$
 $R_{BB2} = 20\Omega$ $t_p = 300\mu s$

*Chicago Standard Transformer Corp.

C-2688

3.7.0 Shorted Class B
SOAR

[See Figure 6]

Test Points:

- $I_{C(\text{peak})} = 0.43A$, $V_{CC} = 35V$
 $R_S = 0.1\Omega$, $R_{BB1} = 10\Omega$, $R_{BB2} = 20\Omega$
 $f = 20Hz$, $T_C = 100^\circ C$

<u>Item</u>	<u>Test Methods and Test Conditions</u>	
4.0.0	<u>Electrical</u> <u>Characteristics</u>	
	Maximum limits unless otherwise noted.	$T_C = 25^{\circ}\text{C}$ [unless otherwise noted]
	Technique:	
	MIL-STD-750A * JS-6	
	C.T. = Curve Tracer	
	P = 300 μs Pulse 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CBO} = 100\text{nA max}$	$V_{CB} = 80\text{V}$, Technique *Method 3036.1D
4.1.2	$I_{CBO} = 10\mu\text{A max}$	$V_{CB} = 80\text{V}$, $T_C = 150^{\circ}\text{C}$ Technique *Method 3036.1 D
4.1.3	$I_{CBO} = 10\mu\text{A max}$	$V_{CB} = 100\text{V}$, Technique *Method 3036.1 D
4.1.4	$I_{CEV} = 100\mu\text{A max}$	$V_{CE} = 60\text{V}$, $V_{EB} = 0.5\text{V}$, $T_C = 150^{\circ}\text{C}$ Technique *Method 3041.1A
4.1.5	$I_{CEO} = 10\mu\text{A max}$	$V_{CE} = 60\text{V}$, Technique *Method 3041.1 A
4.1.6	$I_{EBO} = 10\mu\text{A max}$	$V_{EB} = 5\text{V}$, Technique *Method 3061.1 D
4.1.7	$V_{CEO} = 70\text{V min}$	$I_C = 100\text{ma}$, Technique C.T. [half wave]
4.1.8	$h_{FE} = 40 \text{ min } 145 \text{ max}$	$I_C = 10\text{mA}$, $V_{CE} = 5\text{V}$ Technique C.T.
4.1.9	$h_{FE} = 45 \text{ min } 170 \text{ max}$	$I_C = 100\text{mA}$, $V_{CE} = 5\text{V}$ Technique P
4.1.10	$h_{FE} = 50 \text{ min } 175 \text{ max}$	$I_C = 1.0\text{A}$, $V_{CE} = 5\text{V}$ Technique P

<u>Item</u>	<u>Test Methods and Test Conditions</u>
4.1.11 $h_{FE} = 40 \text{ min } 120 \text{ max}$	$I_C = 5.0A, V_{CE} = 5V$ Technique P
4.1.12 $h_{FE} = 10 \text{ min}$	$I_C = 10A, V_{CE} = 5V$ Technique P
4.1.13 $h_{FE} = 75 \text{ min } 350 \text{ max}$	$I_C = 100mA, V_{CE} = 5V, T_C = 150^{\circ}C$ Technique P
4.1.14 $h_{FE} = 70 \text{ min } 320 \text{ max}$	$I_C = 1.0A, V_{CE} = 5V, T_C = 150^{\circ}C$ Technique P
4.1.15 $h_{FE} = 30 \text{ min } 150 \text{ max}$	$I_C = 5.0A, V_{CE} = 5V, T_C = 150^{\circ}C$ Technique P
4.1.16 $h_{FE} = 30 \text{ min } 90 \text{ max}$	$I_C = 100mA, V_{CE} = 5V, T_C = -55^{\circ}C$ Technique P
4.1.17 $h_{FE} = 30\text{min } 100 \text{ max}$	$I_C = 1.0A, V_{CE} = 5V, T_C = -55^{\circ}C$ Technique P
4.1.18 $h_{FE} = 20 \text{ min } 75 \text{ max}$	$I_C = 5.0A, V_{CE} = 5V, T_C = -55^{\circ}C$ Technique P
4.1.19 $V_{CE(S)} = 0.55V \text{ max}$	$I_C = 5.0A, I_B = 0.5A$ Technique * P
4.1.20 $V_{CE(S)} = 2.0V \text{ max}$	$I_C = 10A, I_B = 1.0A$ Technique* P
4.1.21 $V_{BE(S)} = 1.4V \text{ max}$	$I_C = 5.0A, I_B = 0.5A$ Technique* P
4.1.22 $V_{BE(S)} = 2.0V \text{ max}$	$I_C = 10A, I_B = 1.0A$ Technique* P

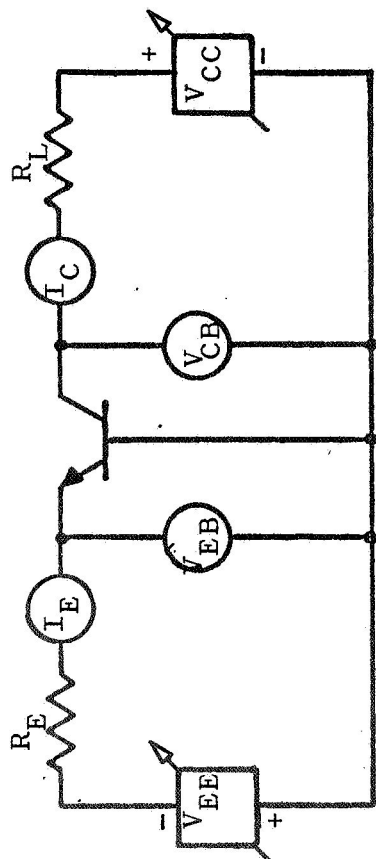
<u>Item</u>	<u>Test Methods and Test Conditions</u>
4.2.0 Dynamic	
4.2.1 $h_{FE} = 1.5 \text{ min } 8.0 \text{ max}$	$I_C = 200\text{mA}$, $V_{CE} = 10\text{V}$, $f = 10\text{MHz}$
4.2.2 $C_{obo} = 350 \text{ pF max}$	$V_{CB} = 10\text{V}$, $I_E = 0$ $f = 1\text{MHz}$
4.2.3 $t_{ON} = 0.5\mu\text{s max}$	circuit specified with registered spec. S2N4150
4.2.4 $t_{OFF} = 2.5\mu\text{s max}$	Circuit specified with registered spec. S2N4150

5.0.0 Thermal Characteristics

- 5.1.1 $\tau_J = 20 \text{ ms min}$
- 5.1.2 $\theta_{JC} = 20 \text{ }^{\circ}\text{C/W max}$
- 5.1.3 $\theta_{JA} = 175 \text{ }^{\circ}\text{C/W max}$

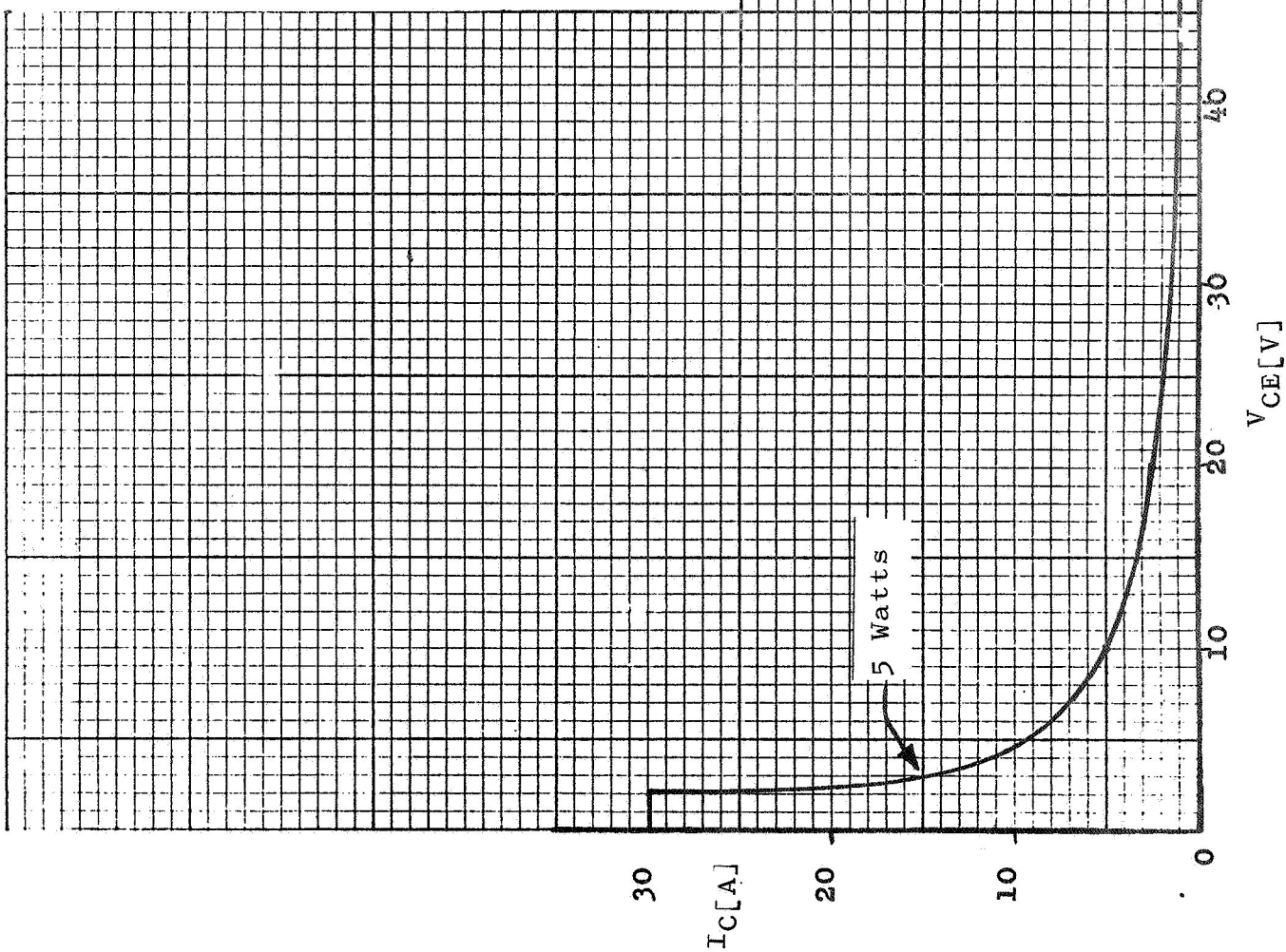
*Test clips 1/4" from case

FORWARD BIASED CONTINUOUS SOAR

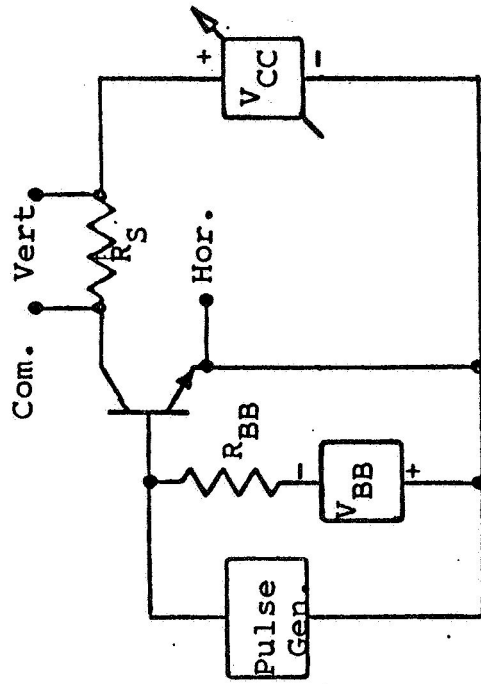


Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12



PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

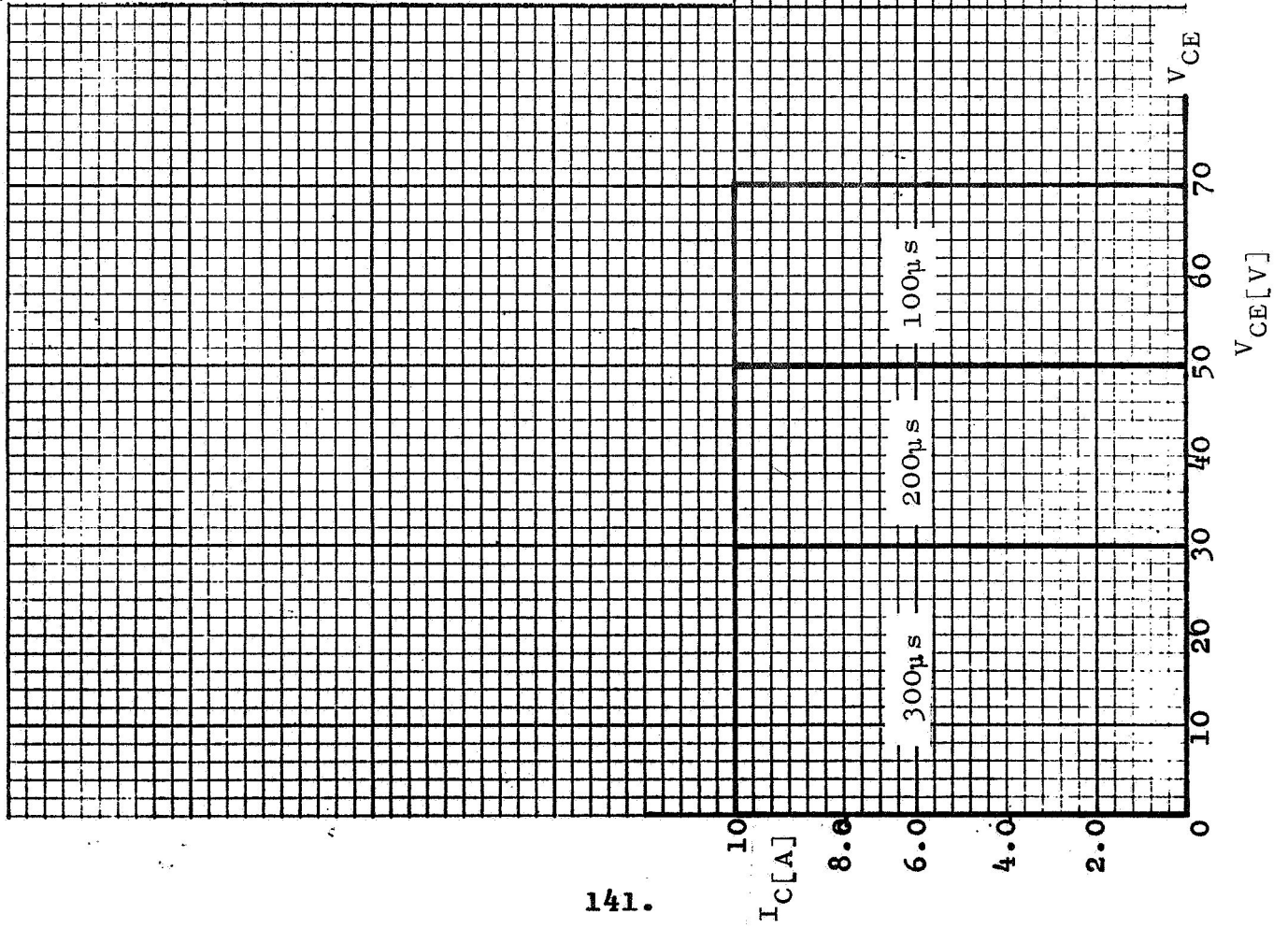


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-RESISTIVE LOAD

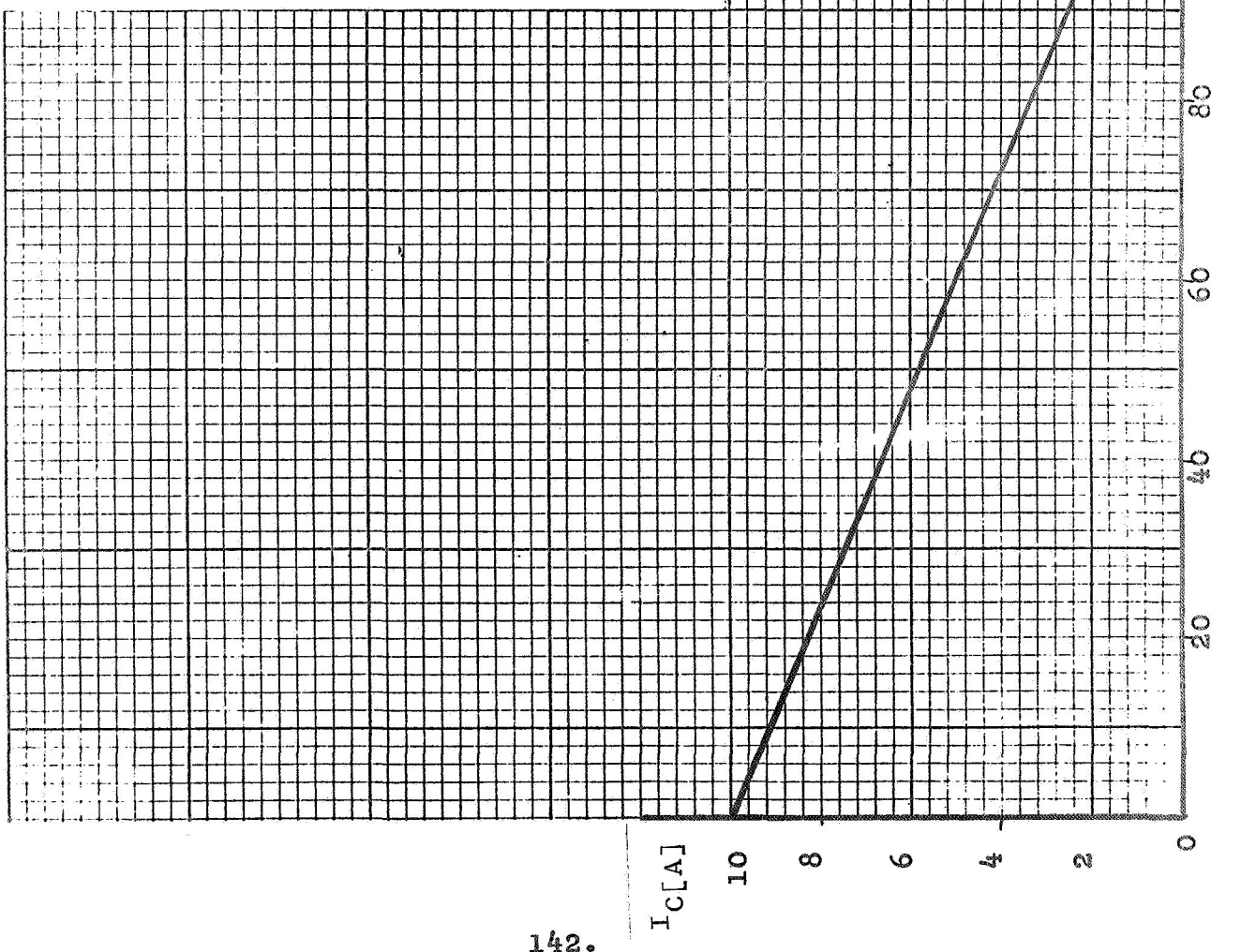
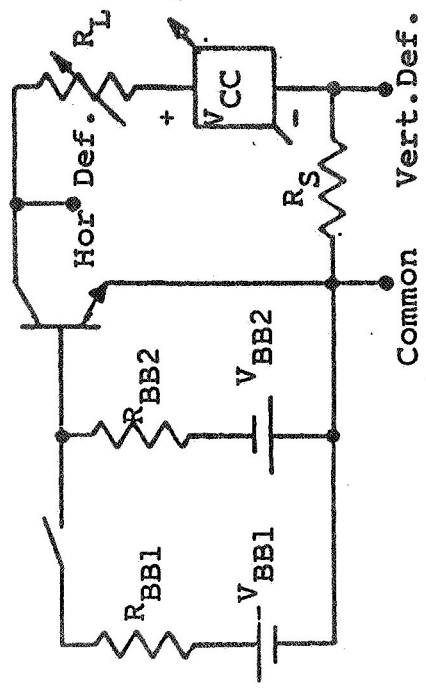
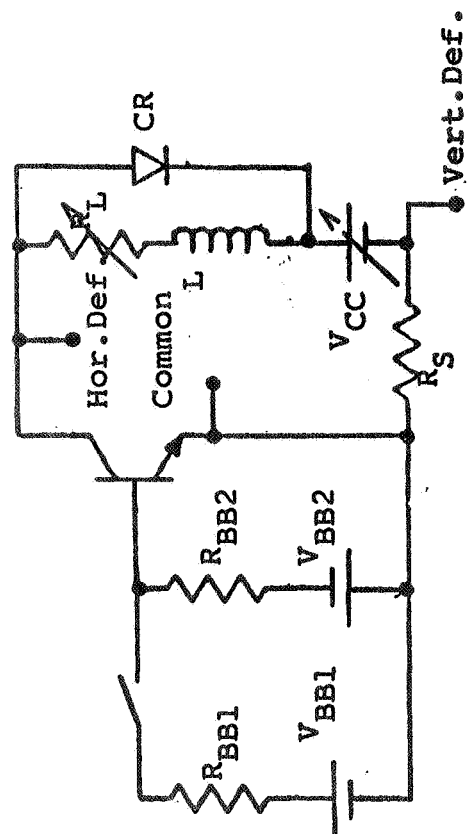


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

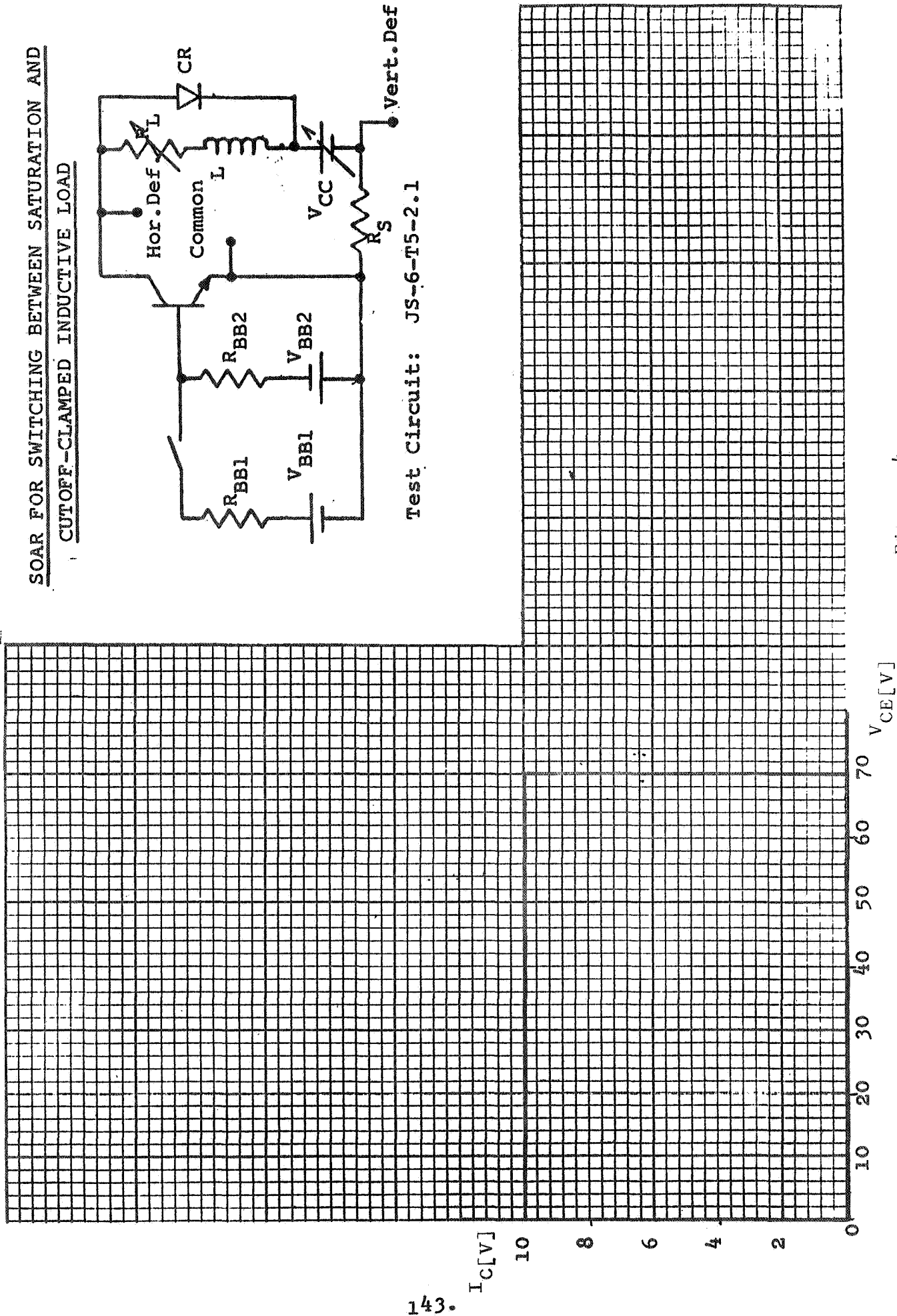
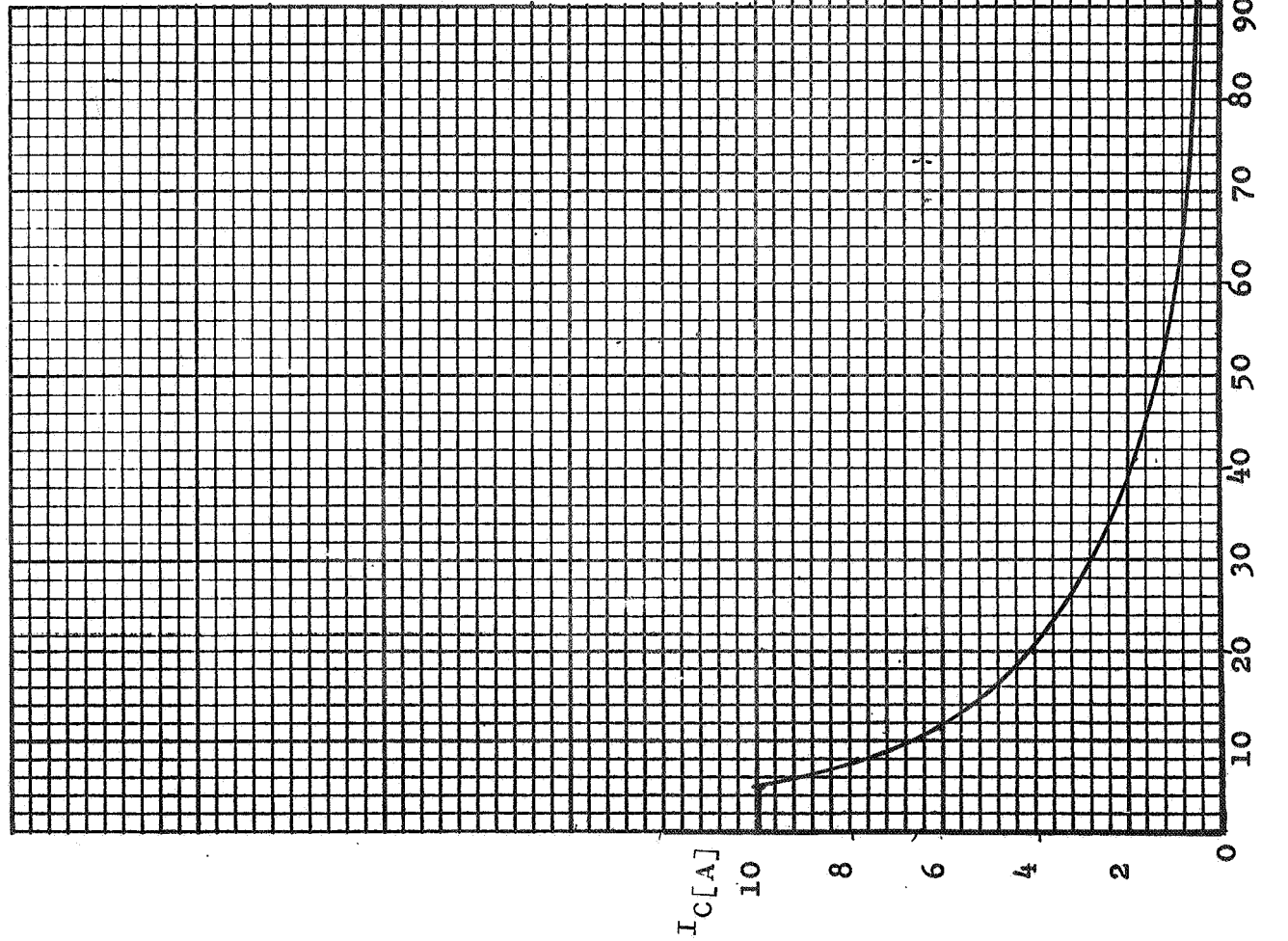
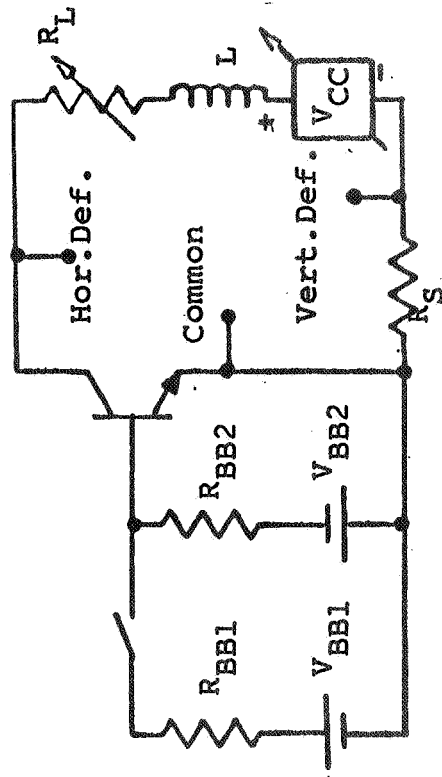


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-UNCLAMPED INDUCTIVE LOAD



144.



Test Circuit: JS-6-T5-2.1

Figure 5

SHORTED CLASS B SOAR

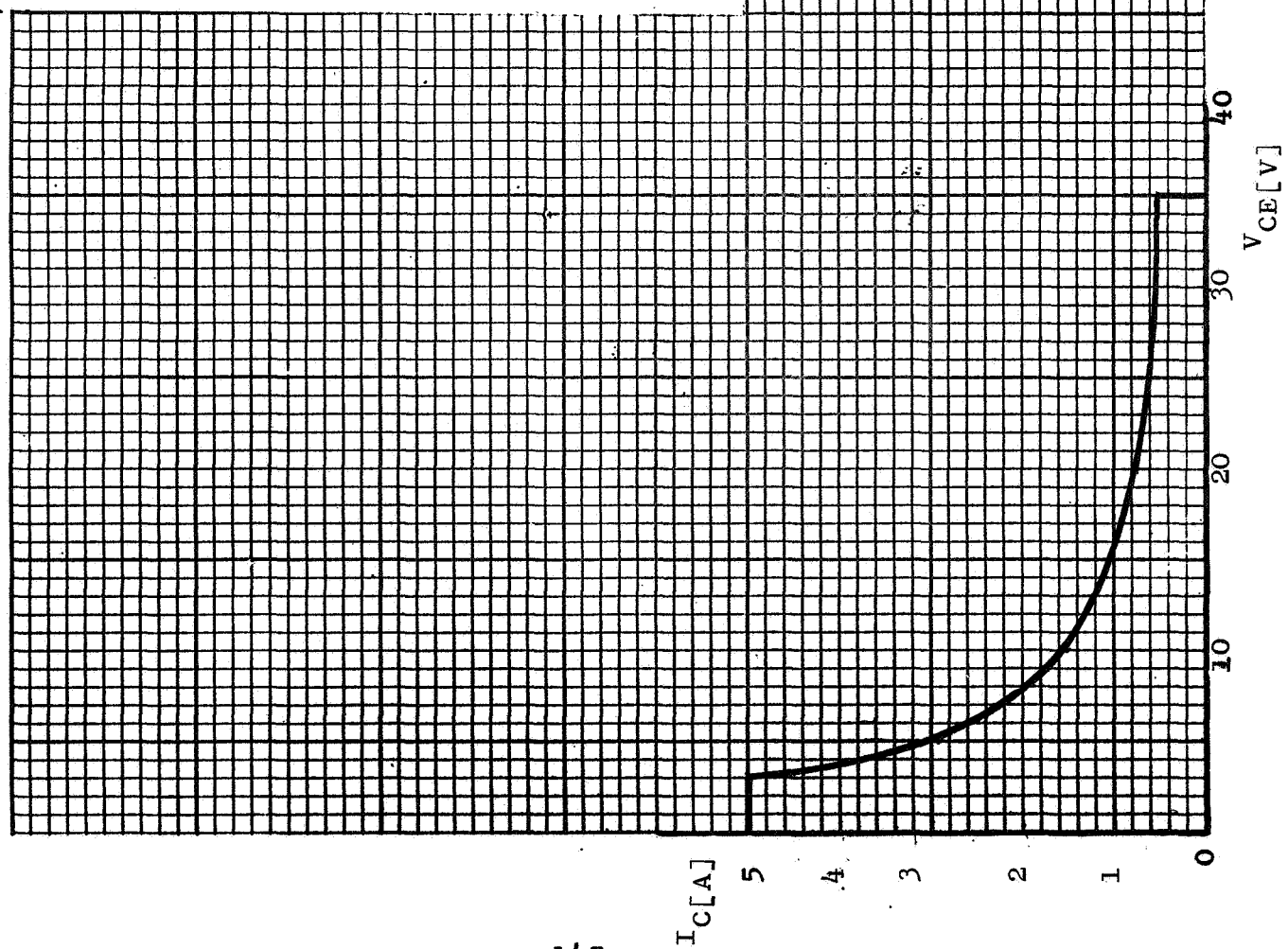
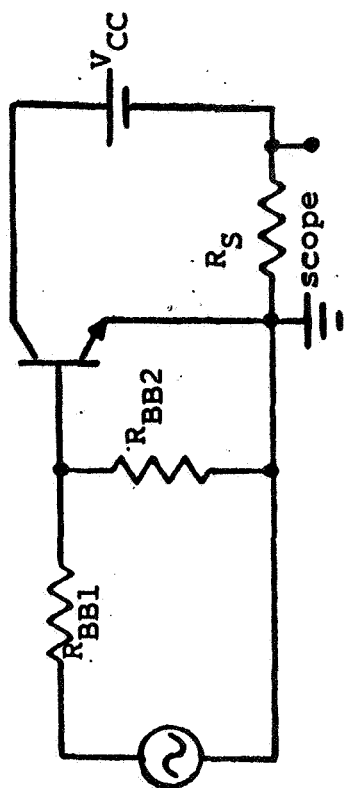


Figure 6

-- TEST REPORT --

SILICON POWER TRANSISTOR

< 2N5559 >

EXAMPLE DEVICE SPECIFICATIONS

-- Manufacturer Bendix --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

The format used in the presentation of this data was recently developed for the registration of transistor specifications.

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item	Registered Data	Test Methods & Test Conditions	Remarks
1.0.0	GENERAL DESCRIPTION		Triode Transistor, Power Switching
1.1.0	Type <input type="text" value="NPN"/>		NPN, PNP, etc.
1.2.0	Material <input type="text" value="Silicon"/>		Ge., Si., etc.
2.0.0	MECHANICAL DATA		Note 1
2.1.0	Outline <input type="text" value="TO-3"/>		Note 2.
2.2.0	Terminal Designation		Indicate all un-connected terminals as "NC".
	1 <input type="text" value="Base"/>		
	2 <input type="text" value="Emitter"/>		
	3 <input type="text" value=""/>		
	case <input type="text" value="Collector"/>		Indicate "I" if all leads insulated from case.
3.0.0	MAXIMUM RATINGS		Note 3
3.1.0	Temperature		
3.1.1	T _{stg} (max) <input type="text" value="200 °C"/>	JS-6-T1.2	Test Methods JS-6-T see "Test Procedures for Verification of Maximum Ratings of Power Transistors". JEDEC Publication No. 65
	T _{stg} (min) <input type="text" value="-65 °C"/>	JS-6-T1.1	
3.1.2	T _J (max) <input type="text" value="200 °C"/>	JS-6-T2	
		T _C <input type="text" value="150 °C"/>	T _C = 75% to 90% T _J Max
		V _{CB} <input type="text" value="≈ 20 V"/> I _C <input type="text" value="2.5 A"/>	
3.1.3	T (Lead) <input type="text" value="235 °C"/>	Distance from case <input type="text" value="1/32 in."/> Time <input type="text" value="10 s"/>	Item 3.1.3 is not required on transistors whose storage temperature is sufficiently high so that the lead temperature test becomes redundant.

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.2.0	Voltage	$T_C = 25^\circ\text{C}$	
3.2.1	V_{CBO} <input type="text" value="150 V"/>	JS-6-T3	
3.2.2	V_{EBO} <input type="text" value="7 V"/>	JS-6-T4	
3.2.3	V_{CEX} <input type="text" value="120 V"/>	JS-6-T5.1	Inductive Method
		I_C ($V_{CE} = V_{CEX}$) <input type="text" value="10 A"/>	R_{BB2} may be infinite
		V_{CC} <input type="text" value="120 V"/> R_L <input type="text" value="10 <math>\Omega</math>"/>	V_{BB2} may be zero
		L <input type="text" value="1 mH"/> CR <input type="text" value="1N1204"/>	Equivalent registered type number of CR, if used, must be given.
		V_{BB1} <input type="text" value="6.2 V"/> R_{BB1} <input type="text" value="3 <math>\Omega</math>"/>	
		V_{BB2} <input type="text" value="0 V"/> R_{BB2} <input type="text" value="5 <math>\Omega</math>"/>	
		Pulse Width <input type="text" value="1 ms"/> Duty Cycle <input type="text" value="2 %"/>	
	or	or	
		JS-6-T5.2	Pulsed Method
	<input type="text" value="V"/>	I_C <input type="text" value="A"/> R_{BB} <input type="text" value=" <math>\Omega</math>"/>	R_{BB} may be zero
		$V_{BB(\text{off})}$ <input type="text" value="V"/>	
		Pulse Width <input type="text" value="ms"/> Duty Cycle <input type="text" value=" %"/>	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.0	Current		
3.3.1	I_C 10 A	JS-6-T6 I_B 2 A T_C \leq °C	Continuous collector current
3.3.2	I_{CM} 15 A	JS-6-T7 $T_C = 25^\circ\text{C}$ R_S 0.1 Ω V_{BB} 0 V R_{BB} $\infty \Omega$ <u>Input Pulse Characteristics</u> Pulse Amplitude 5A Pulse Width 1000 ms Duty Cycle 1 % t_r $\leq 5 \mu\text{s}$ t_f $\leq 5 \mu\text{s}$	Peak collector current
3.3.3	I_B 5 A	JS-6-T8 T_C $\leq 25^\circ\text{C}$	Continuous base current
3.3.4	I_{BM} 7 A	JS-6-T9 $T_C = 25^\circ\text{C}$ <u>Input Pulse Characteristics</u> Pulse Width 1000 ms Duty Cycle 10 % t_r $\leq 5 \mu\text{s}$ t_f $\leq 5 \mu\text{s}$	Peak base current
3.3.5	I_E 12 A	JS-6-T10 I_B 2 A T_C 25 °C	Continuous Emitter current

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.6	I_{EM} A	JS-6-T11 $T_C = 25^\circ\text{C}$ R_S Ω V_{BB} V R_{BB} Ω <u>Input Pulse Characteristics</u> Pulse Width ms Duty Cycle % $t_r \leq$ μs $t_f \leq$ μs	Peak Emitter Current
3.4.0	Power		
3.4.1	P_T 100 W Derating Factor 1 W/°C	JS-6-T12 T_C 100 °C V_{CB} 50 V I_C 2 A	$T_C = 55^\circ\text{C}$ (for device with $T_J (\text{max}) \leq 125^\circ\text{C}$) $T_C = 100^\circ\text{C}$ (for devices with $T_J (\text{max}) > 125^\circ\text{C}$)
3.4.2	P_{TM} 900 W	JS-6-T13 $T_C = 25^\circ\text{C}$ V_{CC} 90 V V_{BB} 0 V R_{BB} 5 Ω <u>Input Pulse Characteristics</u> Pulse Width 0.25 ms Duty Cycle 1 % $t_r \leq$ 5 μs $t_f \leq$ 5 μs	$P_{TM} = I_C V_{CC}$

Item	Registered Data	Test Methods & Test Conditions	Remarks															
3.5.0	Maximum Operating Conditions		Refer to Appendix A															
3.5.1	DC - Attach drawing of operating area V_{CE} vs I_C	T_C 100 °C Fig. 1 1. $I_C = 0.5A$; $V_{CE} = 80V$ 2. $I_C = 2A$; $V_{CE} = 50V$	$T_C = T_C$ (3.4.1) The circuit of JS-6-T12 is recommended.															
3.5.2	Pulsed (Forward Bias Drive) Attach drawing of operating area. V_{CE} vs I_C for one or more pulse widths	JS-6-T14, $T_C = 25^{\circ}C$; Fig. 2 V_{BB} 0 V R_{BB} 5 Ω <u>Input Pulse Characteristics</u> Pulse Width _____ ms Duty Cycle 2 % t_r $\leq 5 \mu s$ $\leq 5 \mu s$	Pulse width shall be 1,2,3, or 5×10^x sec. <table><tr><th>Pulse Width</th><th>V_{CC}</th><th>I_C</th></tr><tr><td>ms</td><td>V</td><td>A</td></tr><tr><td>1. 1 ms @</td><td>60</td><td>10</td></tr><tr><td>2. 0.5 ms @</td><td>80</td><td>10</td></tr><tr><td>3. 0.25 ms @</td><td>90</td><td>10</td></tr></table>	Pulse Width	V_{CC}	I_C	ms	V	A	1. 1 ms @	60	10	2. 0.5 ms @	80	10	3. 0.25 ms @	90	10
Pulse Width	V_{CC}	I_C																
ms	V	A																
1. 1 ms @	60	10																
2. 0.5 ms @	80	10																
3. 0.25 ms @	90	10																
3.6.0	Maximum Operating Conditions for Switching between Saturation and Cutoff		For example refer to Appendix B Specify 3.6.1 or 3.6.2 or 3.6.3															
3.6.1	Resistive Load <																	

OR

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.6.2	<div>Clamped Inductive Load</div> <div>OR</div>	<p>JS-6-T5.1</p> <p>$T_C = 25^{\circ}\text{C}$ Fig. 4</p> <p><u>Input Pulse Characteristics</u></p> <p>Pulse Width 1 ms</p> <p>Duty Cycle 2%</p> <p>$t_r \leq 5\text{ }\mu\text{s}$ $t_f \leq 5\text{ }\mu\text{s}$</p> <p>$R_{BB1} 3\text{ }\Omega$</p> <p>$R_{BB2} 5\text{ }\Omega$</p> <p>$V_{BB1} 6.2\text{ V}$</p> <p>$V_{BB2} 0\text{ V}$</p> <p>$L 1\text{ mH}$</p> <p>JEDEC</p> <p>CR1N1204 The/Type Number of the characteristics must be specified.</p>	<p>Supply graph of Safe Operating Area on the I_C-V_{CE} plane. Safe Operating Area graph must include:</p> <p>V_{CE} (3.2.3)</p> <p>I_C (3.3.1)</p> <p>If one test condition cannot satisfy V_{CE} (3.2.3) and I_C (3.3.1) specify conditions for each test.</p>
3.6.3	<div>Unclamped Inductive Load</div>	<p>JS-6-T5.1 and CR Disconnected</p> <p>$T_C = 25^{\circ}\text{C}$ Fig. 5</p> <p><u>Input Pulse Characteristics</u></p> <p>Pulse Width 20 ms</p> <p>Duty Cycle 30%</p> <p>$t_r \leq 5\text{ }\mu\text{s}$ $t_f \leq 5\text{ }\mu\text{s}$</p> <p>$R_{BB1} 3\text{ }\Omega$</p> <p>$R_{BB2} 5\text{ }\Omega$</p> <p>$V_{BB1} 9.2\text{ V}$</p> <p>$V_{BB2} 5\text{ V}$</p> <p>$L 40\text{ mH}$</p> <p>$Q\text{ of } L \geq 1500 @ f = 1\text{ MHz}$</p> <p>$f_{\text{RESON}}\text{ of } L \geq 8\text{ MHz}$</p> <p>$I_C 4.0\text{ A}$</p> <p>$V_{CC} 22\text{ V}$</p>	<p>For $L = 6.4\text{ mH}$; $I_C = 10\text{ A}$</p> <p>$I_C \geq I_C$ (4.1.7)</p>

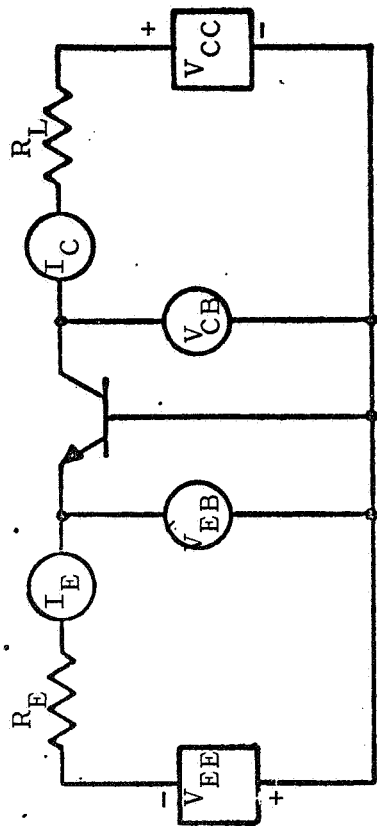
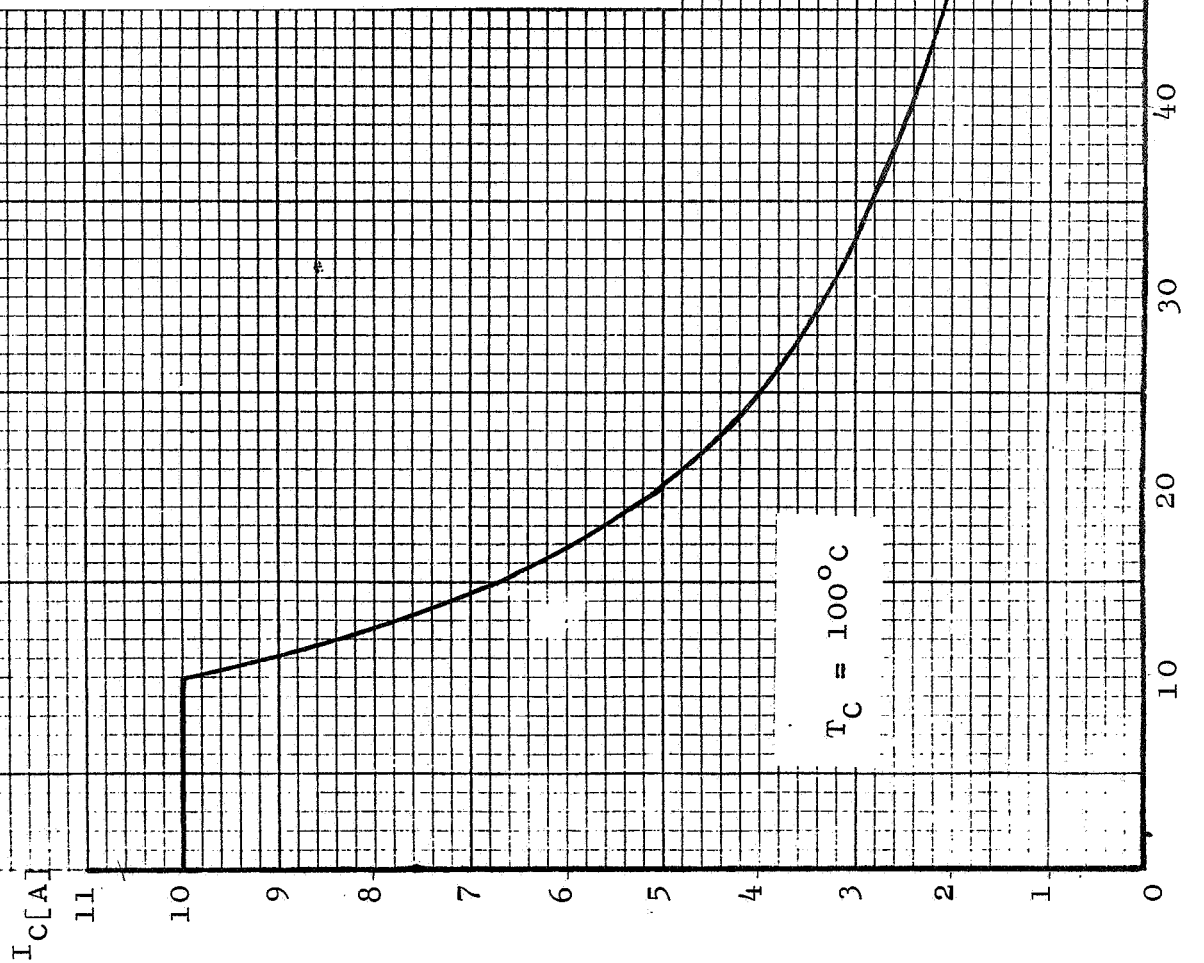
Item	Registered Data	Test Methods & Test Conditions	Remarks
4.0.0	Electrical Characteristics	$T_C = 25^{\circ}\text{C}$ (unless otherwise noted)	Maximum limits unless otherwise noted.
4.1.0	Static		Note 4
4.1.1	I_{CEV} 2 mA	T_C 150 $^{\circ}\text{C}$ V_{CE} 150 V V_{BE} (fwd., rev.) 0 V Technique C.T.	$T_C \geq 1/2 T_J$ (3.1.2)
4.1.2	I_{CEV} 0.5 mA <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;">or</div>	V_{CE} 150 V V_{BE} (fwd., rev.) 0 V Technique C.T. <div style="text-align: center; margin-top: 10px;">or</div>	$V_{CE} \geq 0.9 V_{CB0}$ (3.2.1) Specify 4.1.2 or 4.1.3 and 4.1.4
4.1.3	I_{CB0} mA <div style="text-align: center; margin-top: 10px;">and</div>	V_{CB} V <div style="text-align: center; margin-top: 10px;">and</div>	$V_{CB} = V_{CB0}$ (3.2.1)
4.1.4	V_{EBF} V <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;">and</div>	V_{CB} V Technique 	$V_{CB} = V_{CB0}$ (3.2.1)

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.1.5	I_{EBO} <input type="text" value="0.01 mA"/>	V_{EB} <input type="text" value="7 V"/> Technique <input type="text" value="C.T."/>	$V_{EB} = V_{EBO}$ (3.2.2)
4.1.6	$V_{(BR)CEO}$ <input type="text" value="100 Min V"/>	I_C <input type="text" value="0.2 A"/> I_B <input type="text" value="0 mA"/> Technique <input type="text" value="C.T."/>	Note 5
4.1.7	h_{FE} <input type="text" value="20 Min"/> <input type="text" value="60 Max"/>	V_{CE} <input type="text" value="2 V"/> I_C <input type="text" value="4 A"/> Technique <input type="text" value="C.T."/>	$V_{CE} \leq 2.0V$ or $2 \times V_{CE(sat)}$ (4.1.8) whichever is greater
4.1.8	$V_{CE(sat)}$ <input type="text" value="0.75 Max V"/>	I_C <input type="text" value="4 A"/> I_B <input type="text" value="0.4 A"/> Technique <input type="text" value="C.T."/>	$I_C = I_C$ (4.1.7) Measured 0.064 inches from case.
4.1.9	$V_{BE(sat)}$ <input type="text" value="1.5 Max V"/>	I_C <input type="text" value="4 A"/> I_B <input type="text" value="0.4 A"/> Technique <input type="text" value="C.T."/>	$I_C = I_C$ (4.1.7) Measured 0.064 inches from case.
4.2.0	Dynamic		
4.2.1	t_r <input type="text" value="μs"/>	V_{CC} <input type="text" value=""/> I_{B1} <input type="text" value=""/>	Specify 4.2.1, 4.2.2 and 4.2.3 or 4.2.4 and 4.2.5 $I_C = I_C$ (4.1.7) Switching circuit shall be attached. $I_{B1} = I_B$ (4.1.8)
4.2.2	t_s <input type="text" value="μs"/>	V_{CC} <input type="text" value=""/> I_{B1} <input type="text" value=""/> I_{B2} <input type="text" value=""/>	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
4.2.3	t_f <input type="text" value="μs"/>	V_{CC} <input type="text" value=""/> I_{B1} <input type="text" value=""/> I_{B2} <input type="text" value=""/>	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
	or		

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.2.4	t_{on} 6.0 μs and	V_{CC} 31V I_C 4A Fig. 6	$I_C = I_C$ (4.1.7)
4.2.5	t_{off} 8.0 μs	I_{B1} 0.4A	$I_{B1} = I_B$ (4.1.8)
4.2.6	f_{hfe} [] kHz or	V_{CC} 31V I_C 4A	$I_C = I_C$ (4.1.7)
4.2.7	$ h_{fe} $ 8 min. 40 max	I_{B1} 0.4A I_{B2} -0.4A	$I_{B1} = I_B$ (4.1.8)
		I_C [] A V_{CE} [] V	Specify 4.2.6 or 4.2.7
		V_{CE} 4 V I_C 1 A	Specify 4.2.6 or 4.2.7
		f 0.1 MHz	Note 6
	<u>ADDITIONAL DATA</u>		
3.6.4	Shorted Class B Safe Operating Area	Fig. 7 $I_{Cpeak} = 1A$ $R_S = 0.1\Omega$; $V_{CC} = 80V$ Input Characteristics $R_{BB1} = 1\Omega$; $R_{BB2} = 3\Omega$ $f = 20 \text{ Hz}$; $T_C = 100^\circ C$	
3.6.5	$P_T = 120W$	JS-6-T12; $V_{CE} = 60V$; $I_C = 2A$ $t_p = 1s$; $T_A = 25^\circ C$	Single Pulse
3.6.6	$P_T = 120W$	JS-6-T12; $V_{CE} = 8V$; $I_C = 15A$ $t_p = 1s$; $T_A = 25^\circ C$	Single Pulse
4.1.10	$I_{CEO} = 100 \mu A$ max	$V_{CE} = 80V$, Technique C.T.	
4.1.11	$V_{CES} = 125V$ min.	$I_C = 10 \text{ mA}$; $R_{CC} = 5K \Omega$ Technique C.T.	
4.1.12	$V_{EBO} = 7V$ min.	$I_E = 10 \text{ mA}$; $R_{BB} = 5K \Omega$ Technique C.T.	
4.1.13	$h_{FE} = 40$ min.	$I_C = 0.1A$; $V_{CE} = 2V$; Technique C.T.	
4.1.14	$V_{CE(sat)} = 1.2V$ max.	$I_C = 10A$; $I_B = 1A$; Technique C.T.	Measured 0.064 inches from case
4.1.15	$V_{BE(sat)} = 2.0V$ max.	$I_C = 10A$; $I_B = 1A$; Technique C.T.	
4.1.16	$V_{BE} = 1.4V$ max.	$I_C = 4A$; $V_{CE} = 2V$; Technique C.T.	

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.1.17	$V_{BE} = 0.55 \text{ V min.}$ $V_{BE} = 0.65 \text{ V max.}$	$I_C = 0.1\text{A}; V_{CE} = 2\text{V};$ Technique C.T.	Measured 0.064" from case
4.1.18	$h_{FE} = 40 \text{ min.}$	$I_C = 0.5\text{A}; V_{CE} = 2\text{V};$ Technique C.T.	
4.1.19	$h_{FE} = 15 \text{ min.}$	$I_C = 4\text{A}, V_{CE} = 2\text{V};$ Technique C.T. $T_C = -55^\circ\text{C}$	Time to reach 63% of equilibrium temperature for P_T step input.
4.1.20	$C_{obo} = 400 \text{ pF max.}$	$V_{CB} = 10\text{V}; f = 1 \text{ MHz}$	
4.3.0	$\theta_{JC} = 1^\circ\text{C/W max.}$	$I_C = 1\text{A}; V_{CE} = 20\text{V}$	
4.3.1	$\theta_{JA} = 25^\circ\text{C/W max.}$	$I_C = 1\text{A}; V_{CE} = 2\text{V}$	
4.3.2	$\tau_J = 15 \text{ ms}$	$I_C = 1\text{A}; V_{CE} = 20\text{V}$	

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ\text{C}$, $I_C \geq I_{CE0}$

Test Circuit: JS-6-T12

Figure 1

PULSED OPERATION - FORWARD BIASED PULSED SOAR

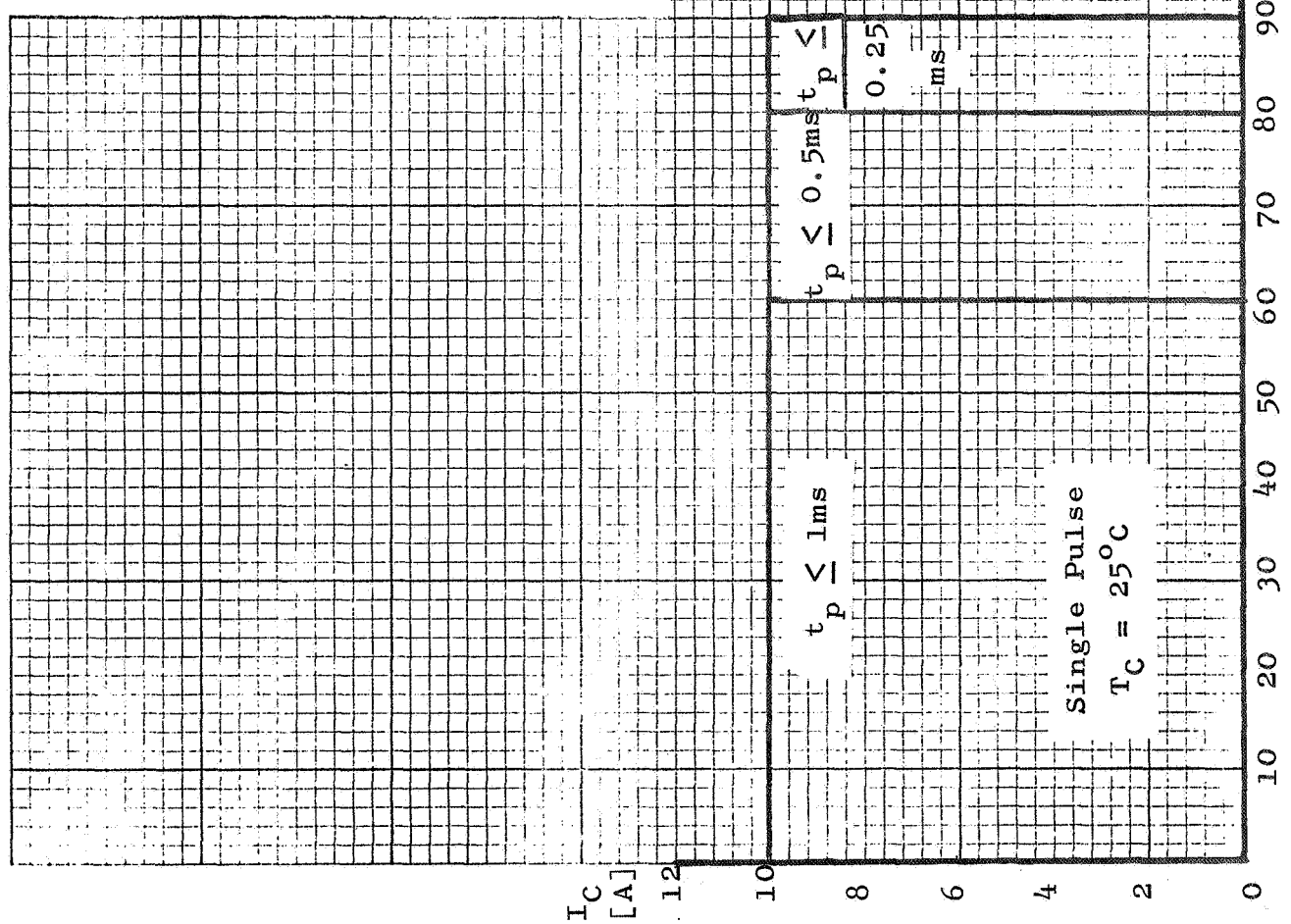
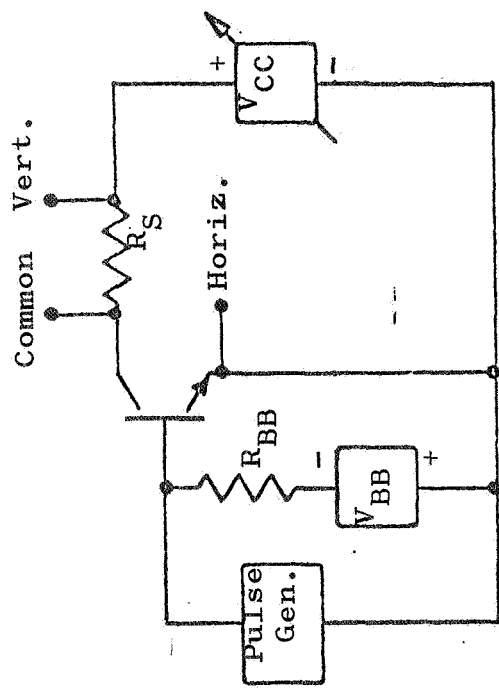
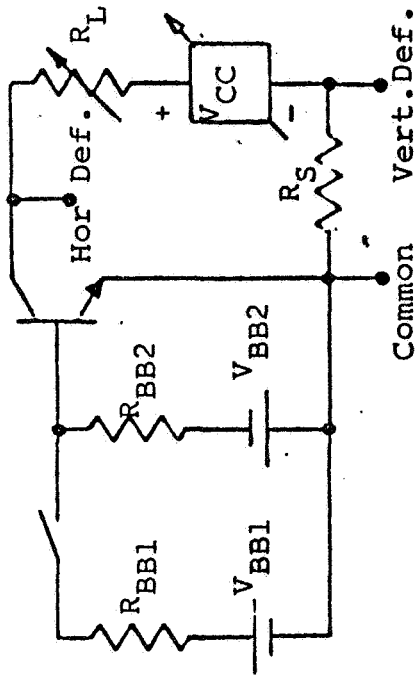
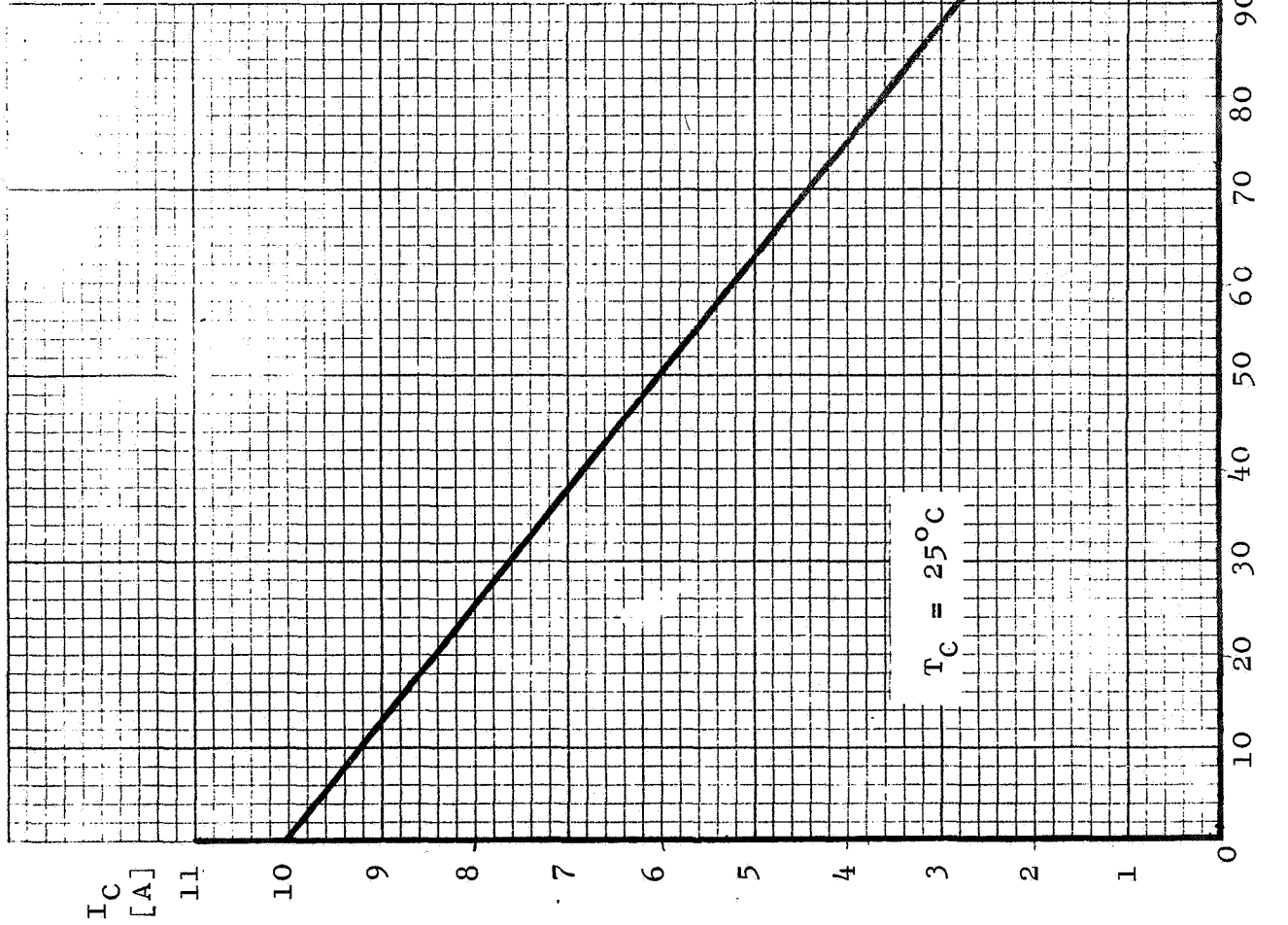


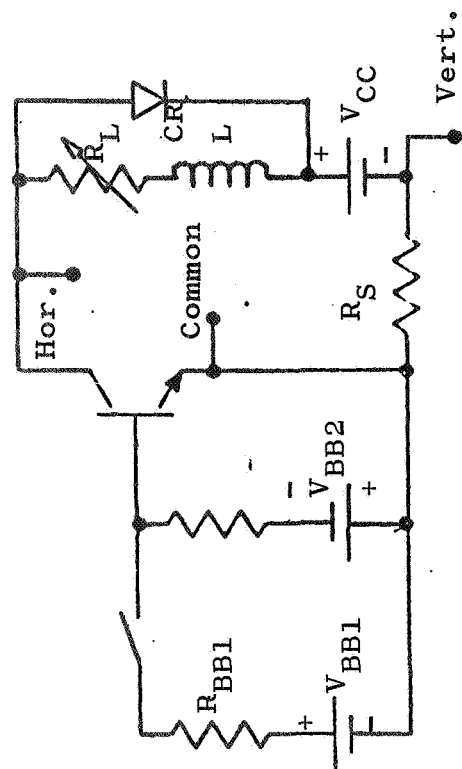
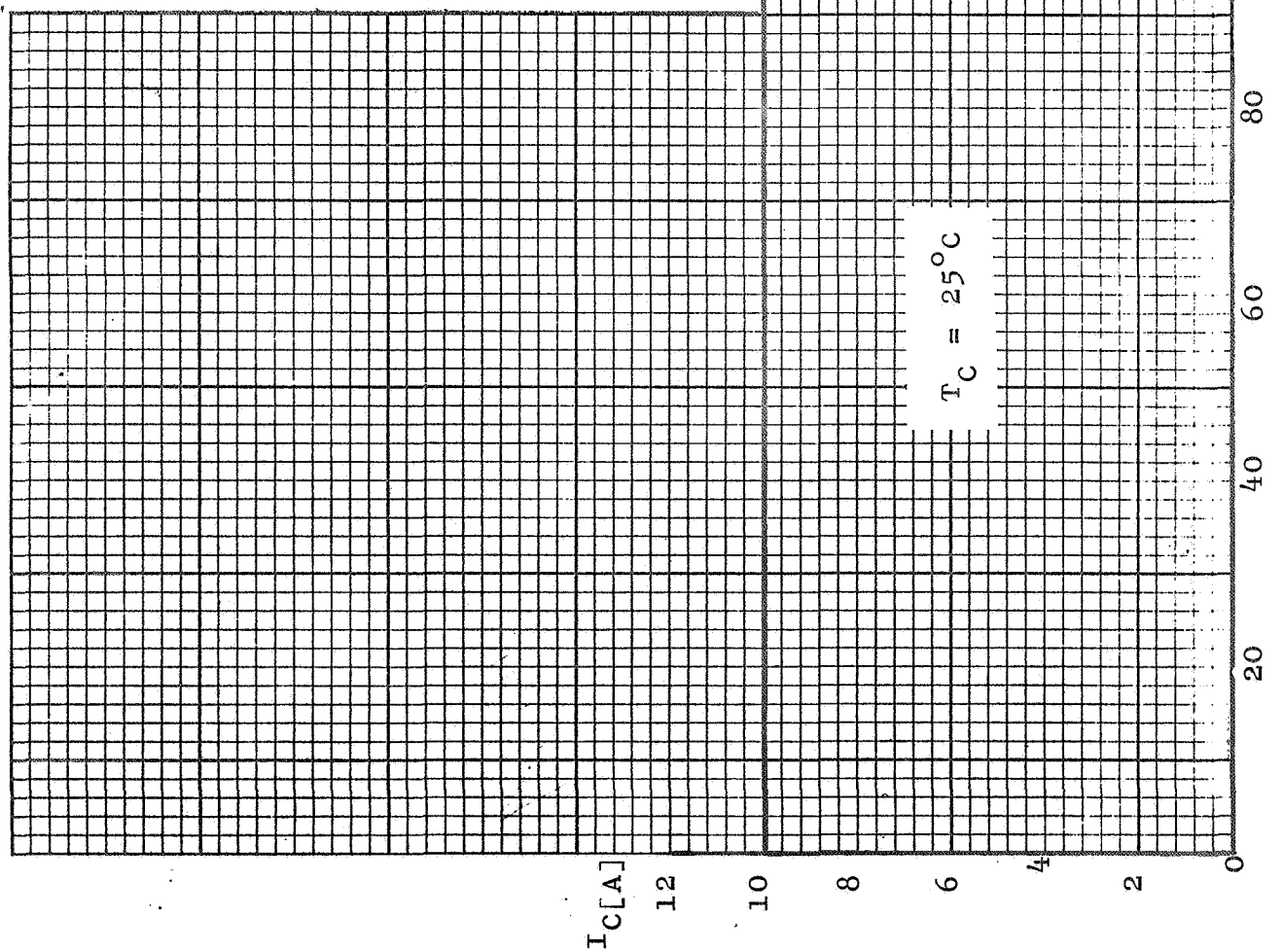
Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1

**SOAR FOR SWITCHING BETWEEN SATURATION &
CUTOFF - CLAMPED INDUCTIVE LOAD**



Test Circuit JS-6-T5.1

Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD

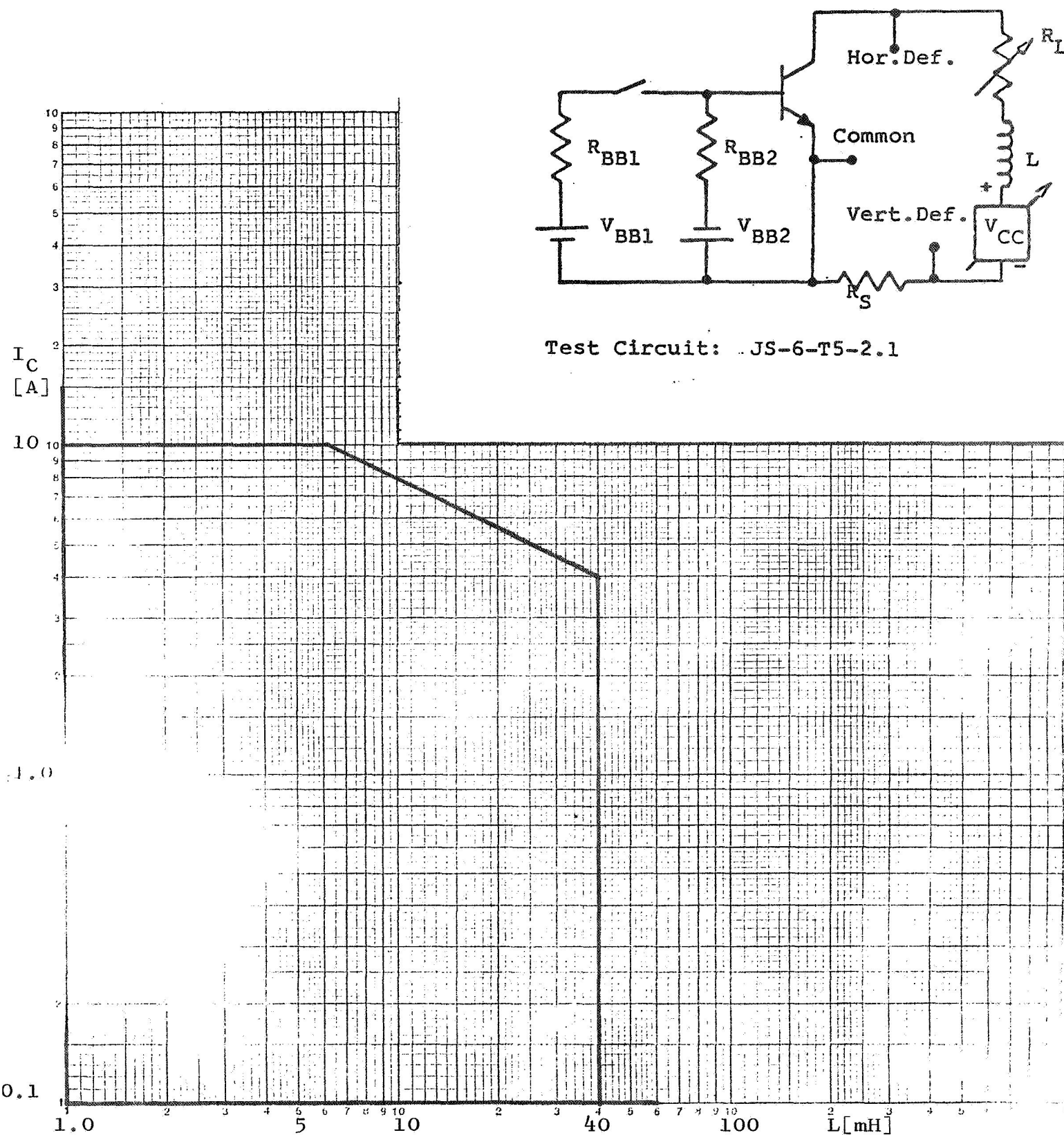


Figure 5

SWITCHING TEST CIRCUIT

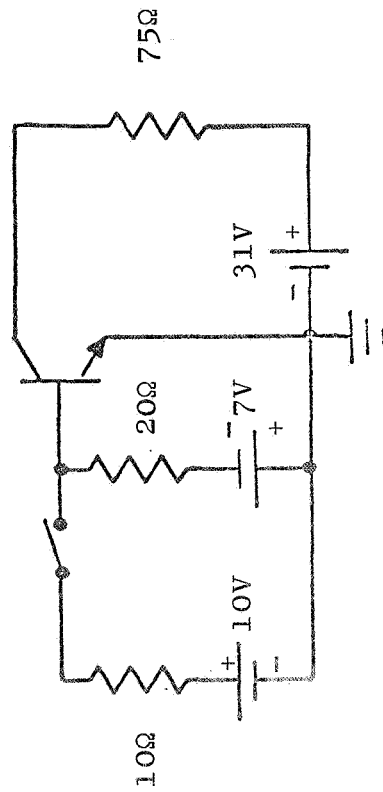
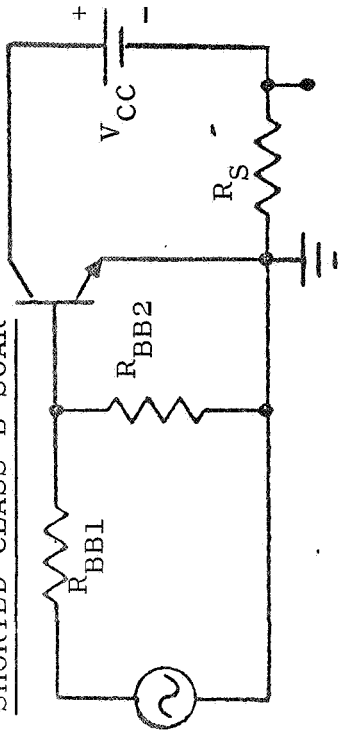
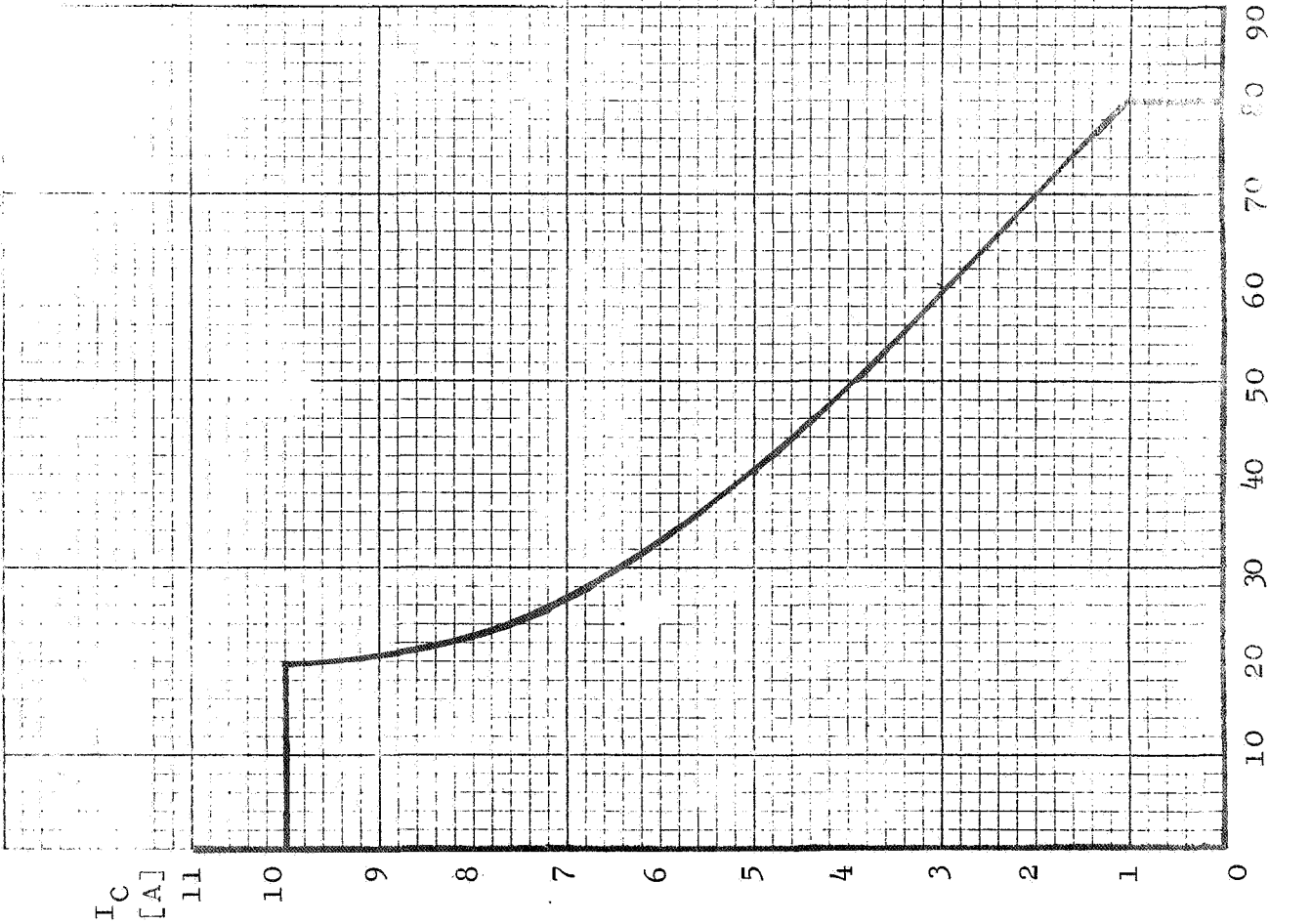


Figure 6

SHORTED CLASS B SOAR



Test Circuit: $T_C \leq 100^\circ\text{C}$,
 $f \geq 20\text{Hz}$



-- TEST REPORT --

SILICON POWER TRANSISTOR
< 2N5560 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer Bendix --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

The format used in the presentation of this data
was recently developed for the registration of
transistor specifications.

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item	Registered Data	Test Methods & Test Conditions	Remarks
1.0.0	GENERAL DESCRIPTION		Triode Transistor Power Switching
1.1.0	Type <input type="text" value="NPN"/>		NPN, PNP, etc.
1.2.0	Material <input type="text" value="Silicon"/>		Ge., Si., etc.
2.0.0	MECHANICAL DATA		Note 1
2.1.0	Outline <input type="text" value="TO-63"/>		Note 2
2.2.0	Terminal Designation		Indicate all un-connected terminals as "NC".
	1 <input type="text" value="Emitter"/>		
	2 <input type="text" value="Base"/>		
	3 <input type="text" value="Collector"/>		
	case <input type="text" value="Collector"/>		Indicate "I" if all leads insulated from case.
3.0.0	MAXIMUM RATINGS		Note 3
3.1.0	Temperature		
3.1.1	T _{stg} (max) <input type="text" value="200 °C"/>	JS-6-T1.2	Test Methods JS-6-T____ See "Test Procedures for Verification of Maximum Ratings of Power Transistors" JEDEC Publication No.65
	T _{stg} (min) <input type="text" value="-65 °C"/>	JS-6-T1.1	
3.1.2	T _{J(max)} <input type="text" value="200 °C"/>	JS-6-T2	
		T _C <input type="text" value="150 °C"/> P _T = 75W	T _C = 75% to 90% T _J Max
		V _{CB} <input type="text" value="≈ 4 V"/> I _C <input type="text" value="15 A"/>	
3.1.3	T (Lead) <input type="text" value="230 °C"/>	Distance from case <input type="text" value="1/16 in."/>	Item 3.1.3 is not required on transistors whose storage temperature is sufficiently high so that the lead temperature test becomes redundant.
		Time <input type="text" value="10 s"/>	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.2.0	Voltage	$T_C = 25^\circ\text{C}$	
3.2.1	V_{CBO} 175 V	JS-6-T3	
3.2.2	V_{EBO} 8 V	JS-6-T4	
3.2.3	V_{CEX} 120 V	JS-6-T5.1	Inductive Method
		I_C ($V_{CE} = V_{CEX}$) 30 A	R_{BB2} may be infinite
		V_{CC} 120 V R_L 3.8 Ω	V_{BB2} may be zero
		L 1 mH CR 1N1202	Equivalent registered type number of CR, if used, must be given.
		V_{BB1} 12.2 V R_{BB1} 3 Ω	
		V_{BB2} 6 V R_{BB2} 20 Ω	
		Pulse Width 1 ms Duty Cycle 2 %	
	or	or	
		JS-6-T5.2	Pulsed Method
	V	I_C A R_{BB} Ω	R_{BB} may be zero
		$V_{BB(\text{off})}$ V	
		Pulse Width ms Duty Cycle %	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.0	Current		
3.3.1	I_C 30 A	JS-6-T6 I_B 3 A T_C $\leq 25^\circ\text{C}$	Continuous collector current
3.3.2	I_{CM} A	JS-6-T7 $T_C = 25^\circ\text{C}$ R_S Ω V_{BB} V R_{BB} Ω <u>Input Pulse Characteristics</u> Pulse Amplitude V Pulse Width ms Duty Cycle % t_r \leq μs t_f \leq μs	Peak collector current
3.3.3	I_B 10 A	JS-6-T8 T_C $\leq 25^\circ\text{C}$	Continuous base current
3.3.4	I_{BM} A	JS-6-T9 $T_C = 25^\circ\text{C}$ <u>Input Pulse Characteristics</u> Pulse Width ms Duty Cycle % t_r \leq μs t_f \leq μs	Peak base current
3.3.5	I_E 33 A	JS-6-T10 I_B 3 A T_C 25 $^\circ\text{C}$	Continuous Emitter current

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.6	I_{EM} [] A	JS-6-T11 $T_C = 25^\circ\text{C}$ R_S [] Ω V_{BB} [] V R_{BB} [] Ω <u>Input Pulse Characteristics</u> Pulse Width [] μs Duty Cycle [] % $t_r \leq$ [] μs $t_f \leq$ [] μs	Peak Emitter Current
3.4.0	Power		
3.4.1	P_T [] 150 W	JS-6-T12 T_C [] 100°C V_{CB} [] 4 V I_C [] 30 A Derating Factor [] 1.5 W/ $^\circ\text{C}$	$T_C = 55^\circ\text{C}$ (for device with $T_J(\text{max}) \leq 125^\circ\text{C}$) $T_C = 100^\circ\text{C}$ (for devices with $T_J(\text{max}) > 125^\circ\text{C}$)
3.4.2	P_{TM} [] 3600 W	JS-6-T13 $T_C = 25^\circ\text{C}$ V_{CC} [] 120 V V_{EB} [] 6 V R_{EB} [] 20 Ω <u>Input Pulse Characteristics</u> Pulse Width [] 0.125 ms Duty Cycle [] 0.4 % $t_r \leq$ [] 5 μs $t_f \leq$ [] 5 μs	$P_{TM} = I_C V_{CC}$

Item	Registered Data	Test Methods & Test Conditions	Remarks															
3.5.0	Maximum Operating Conditions		Refer to Appendix A															
3.5.1	DC - Attach drawing of operating area V_{CE} vs I_C	T_C <input type="text" value="100"/> $^{\circ}C$ Fig. 1 1. $I_C = 130$ mA; $V_{CE} = 120V$ 2. $I_C = 450$ mA; $V_{CE} = 60V$	$T_C = T_C$ (3.4.1) The circuit of JS-6-T12 is recommended.															
3.5.2	Pulsed (Forward Bias Drive) Attach drawing of operating area. V_{CE} vs I_C for one or more pulse widths	JS-6-T14 ; Fig. 2 $T_C = 25^{\circ}C$ V_{BB} <input type="text" value="6"/> V R_{BB} <input type="text" value="20"/> Ω <u>Input Pulse Characteristics</u> Pulse Width <input type="text" value=""/> ms Duty Cycle <input type="text" value="0.4"/> % t_r <input type="text" value="≤ 5"/> μs <input type="text" value="≤ 5"/> μs	Pulse width shall be 1,2,3, or 5×10^x sec. <table><tr><th>Pulse Width [ms]</th><th>V_{CC} [V]</th><th>I_C [A]</th></tr><tr><td>1. 5 @</td><td>30</td><td>30</td></tr><tr><td>2. 1 @</td><td>50</td><td>30</td></tr><tr><td>3. 0.5 @</td><td>75</td><td>30</td></tr><tr><td>4. 0.125 @</td><td>120</td><td>30</td></tr></table>	Pulse Width [ms]	V_{CC} [V]	I_C [A]	1. 5 @	30	30	2. 1 @	50	30	3. 0.5 @	75	30	4. 0.125 @	120	30
Pulse Width [ms]	V_{CC} [V]	I_C [A]																
1. 5 @	30	30																
2. 1 @	50	30																
3. 0.5 @	75	30																
4. 0.125 @	120	30																
3.6.0	Maximum Operating Conditions for Switching between Saturation and Cutoff		For example refer to Appendix B Specify 3.6.1 or 3.6.2 or 3.6.3															
3.6.1	Resistive Load <																	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.6.2	Clamped Inductive Load OR	JS-6-T5.1; Fig. 4 T _C = 25 °C <u>Input Pulse Characteristics</u> Pulse Width 2 ms Duty Cycle 2 % t _r ≤ 5 μs t _f ≤ 5 μs R _{BB1} 3 Ω R _{BB2} 20 Ω V _{BE1} 12.2 V V _{BE2} 6 V L 1 mH JEDEC CR 1N1202 The Type Number of the characteristics must be specified.	Supply graph of Safe Operating Area on the I _C -V _{CE} plane. Safe Operating Area graph must include: V _{CE} (3.2.3) = 120V I _C (3.3.1) = 30A If one test condition cannot satisfy V _{CE} (3.2.3) and I _C (3.3.1) specify conditions for each test.
3.6.3	Unclamped Inductive Load	JS-6-T5.1 and CR Disconnected T _C = 25 °C ; Fig. 5 <u>Input Pulse Characteristics</u> Pulse Width 5 ms Duty Cycle 5 % t _r ≤ 5 μs t _f ≤ 5 μs R _{BB1} 3 Ω R _{BB2} 20 Ω V _{BE1} 12.2 V V _{BE2} 6 V L 10 mH Q of L ≥ 1500 f _{RESON} of L ≥ 9.5 MHz I _C 1.4 A V _{CC} 36 V	For L = 0.1 mH; I _C = 30A I _C ≥ I _C (4.1.7)

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.0.0	Electrical Characteristics	$T_C = 25^{\circ}\text{C}$ (unless otherwise noted)	Maximum limits unless otherwise noted.
4.1.0	Static		Note 4
4.1.1	I_{CEV} 0.100 mA	T_C 125 $^{\circ}\text{C}$ V_{CZ} 100 V V_{BE} (fwd., rev.) 0 V Technique C.T.	$T_C \geq 1/2 T_J$ (3.1.2)
4.1.2	I_{CEV} 1.0 mA <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;">or</div>	V_{CE} 175 V V_{BE} (fwd., rev.) 0 V Technique C.T. <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;">or</div>	$V_{CE} \geq 0.9 V_{CBO}$ (3.2.1) Specify 4.1.2 or 4.1.3 and 4.1.4
4.1.3	I_{CBO} mA <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;">and</div>	V_{CB} V <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;">and</div>	$V_{CB} = V_{CBO}$ (3.2.1)
4.1.4	V_{EBF} V <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;"> </div>	V_{CB} V Technique 	$V_{CB} = V_{CBO}$ (3.2.1)

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.1.5	I_{EBO} <input type="text" value="0.010 mA"/>	V_{EB} <input type="text" value="8 V"/> Technique <input type="text" value="C.T."/>	$V_{EB} = V_{EBO}$ (3.2.2)
4.1.6	$V_{(BR)CEO}$ <input type="text" value="120 Min V"/>	I_C <input type="text" value="25 mA"/> I_B <input type="text" value="0 mA"/> Technique <input type="text" value="C.T."/>	Note 5
4.1.7	h_{FE} <input type="text" value="30 Min"/> <input type="text" value="90 Max"/>	V_{CE} <input type="text" value="2 V"/> I_C <input type="text" value="15 A"/> Technique <input type="text" value="C.T."/>	$V_{CE} \leq 2.0V$ or $2 \times V_{CE(sat)}$ (4.1.8) whichever is greater
4.1.8	$V_{CE(sat)}$ <input type="text" value="0.8 Max V"/>	I_C <input type="text" value="15 A"/> I_B <input type="text" value="1.5 A"/> Technique <input type="text" value="C.T."/>	$I_C = I_C$ (4.1.7) Measured 5/16" from case.
4.1.9	$V_{BE(sat)}$ <input type="text" value="1.3 Max V"/>	I_C <input type="text" value="15 A"/> I_B <input type="text" value="1.5 A"/> Technique <input type="text" value="C.T."/>	$I_C = I_C$ (4.1.7)
4.2.0	Dynamic		
4.2.1	t_T <input type="text" value="μs"/>	V_{CC} <input type="text" value=""/> I_{B1} <input type="text" value=""/>	Specify 4.2.1, 4.2.2 and 4.2.3 or 4.2.4 and 4.2.5 $I_C = I_C$ (4.1.7) Switching circuit shall be attached. $I_{B1} = I_B$ (4.1.8)
4.2.2	t_S <input type="text" value="μs"/>	V_{CC} <input type="text" value=""/> I_{B1} <input type="text" value=""/> I_{B2} <input type="text" value=""/>	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
4.2.3	t_f <input type="text" value="μs"/>	V_{CC} <input type="text" value=""/> I_{B1} <input type="text" value=""/> I_{B2} <input type="text" value=""/>	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)

or

Item	Registered Data		Test Methods & Test Conditions		Remarks
4.2.4	t_{on}	<div>1.0 μs</div> <div>and</div>	V_{CC} 31 V	I_C $\approx 15A$	$I_C = I_C$ (4.1.7)
4.2.5	t_{off}	2.0 μs	I_{B1} $\approx 1.5 A$	Fig. 6	$I_{B1} = I_B$ (4.1.8)
			V_{CC} 31 V	I_C 15 A	$I_C = I_C$ (4.1.7)
			I_{B1} $\approx 1.5 A$	I_{B2} $\approx 1.5 A$	$I_{B1} = I_B$ (4.1.8)
4.2.6	f_{hfe}	<div>[] kHz</div> <div>or</div>	I_C A	V_{CE} V	Specify 4.2.6 or 4.2.7
4.2.7	$ h_{fe} $	<div>8 min</div> <div>20 max</div>	V_{CE} 10 V	I_C 1 A	Specify 4.2.6 or 4.2.7
			5 kHz		Note 6

Item	Registered Data	Test Methods & Test Conditions	Remarks
	<u>ADDITIONAL DATA</u>		
3.6.4	Shorted Class B Safe Operating Area	Fig. 7 $R_S = 0.1\Omega$ 1. $I_C = 1.1A$; $V_{CC} = 60V$ 2. $I_C = 390\text{ mA}$; $V_{CC} = 120V$ Input Characteristics $R_{BB1} = 1\Omega$; $R_{BB2} = 3\Omega$ $f = 20\text{ Hz}$; $T_C = 100^\circ\text{C}$	
3.6.5	$P_T = 40W$	JS-6-T12; $V_{CE} = 60$; $I_C = 0.66A$ $t_p = 1s$; $T_A = 25^\circ\text{C}$	
4.1.10	$I_{CEO} = 25\text{ }\mu\text{A max.}$	$V_{CE} = 80V$ Technique C.T.	
4.1.11	$V_{CES} = 125V\text{ min.}$	$I_C = 10\text{ mA}$; $R_{CC} = 500\Omega$ Technique C.T.	
4.1.12	$V_{EBO} = 8V\text{ min}$	$I_E = 200\text{ mA}$; $R_{BB} = 500\Omega$ Technique C.T.	
4.1.13	$h_{FE} = 40\text{ min}$	$I_C = 0.1A$; $V_{CE} = 2V$ Technique C.T.	
4.1.14	$h_{FE} = 40\text{ min}$ $h_{FE} = 100\text{ max}$	$I_C = 5A$; $V_{CE} = 1.5V$	
4.1.15	$h_{FE} = 10\text{ min}$	$I_C = 15A$; $V_{CE} = 2V$	After exposure level of $\phi = 1 \times 10^{13}\text{ nvt}$ (Total integrated neutron flux with energy levels greater than 10 KeV)
4.1.16	$V_{CE(sat)} = 1.5V\text{ max}$	$I_C = 30A$; $I_B = 3A$; Technique C.T.	Measured 5/16" from case.
4.1.17	$V_{BE(sat)} = 2.0V\text{ max}$	$I_C = 30A$; $I_B = 3A$; Technique C.T.	
4.1.18	$C_{obo} = 600\text{ pF max.}$	$V_{CB} = 10V$; $f = 1\text{ MHz}$	
4.3.0	$\theta_{JC} = 0.67^\circ\text{C/W max.}$	$I_C = 1A$; $V_{CE} = 20V$	
4.3.1	$\theta_{JA} = 30^\circ\text{C/W}$	$I_C = 1A$; $V_{CE} = 2V$	
4.3.2	$\tau_J = 25\text{ ms min.}$	$I_C = 1A$; $V_{CE} = 20V$	Time to reach 63% of equilibrium temperature for P_T step input.

FORWARD BIASED CONTINUOUS SOAR

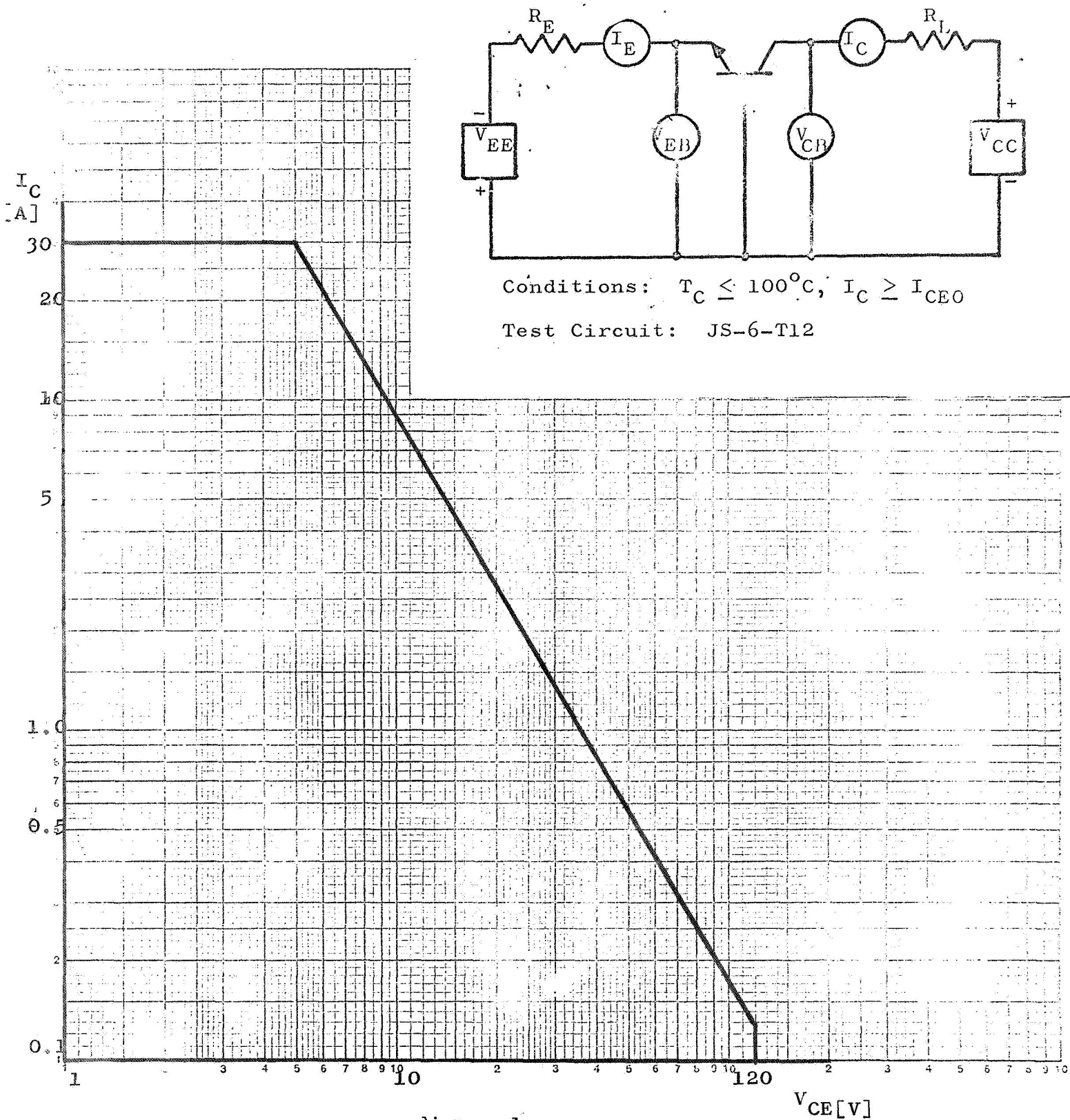
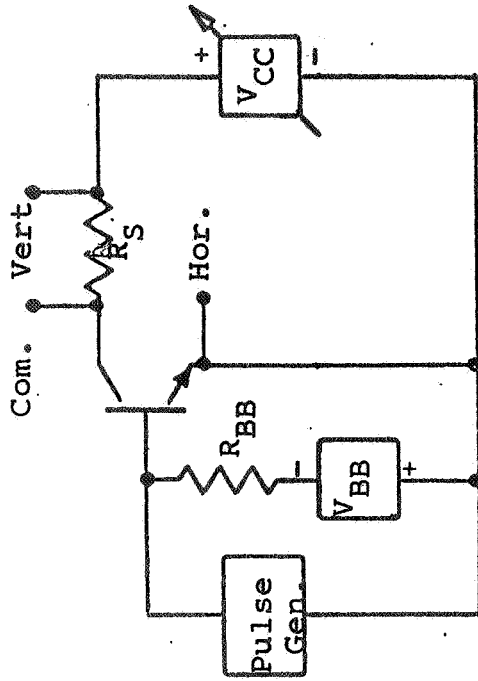


Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

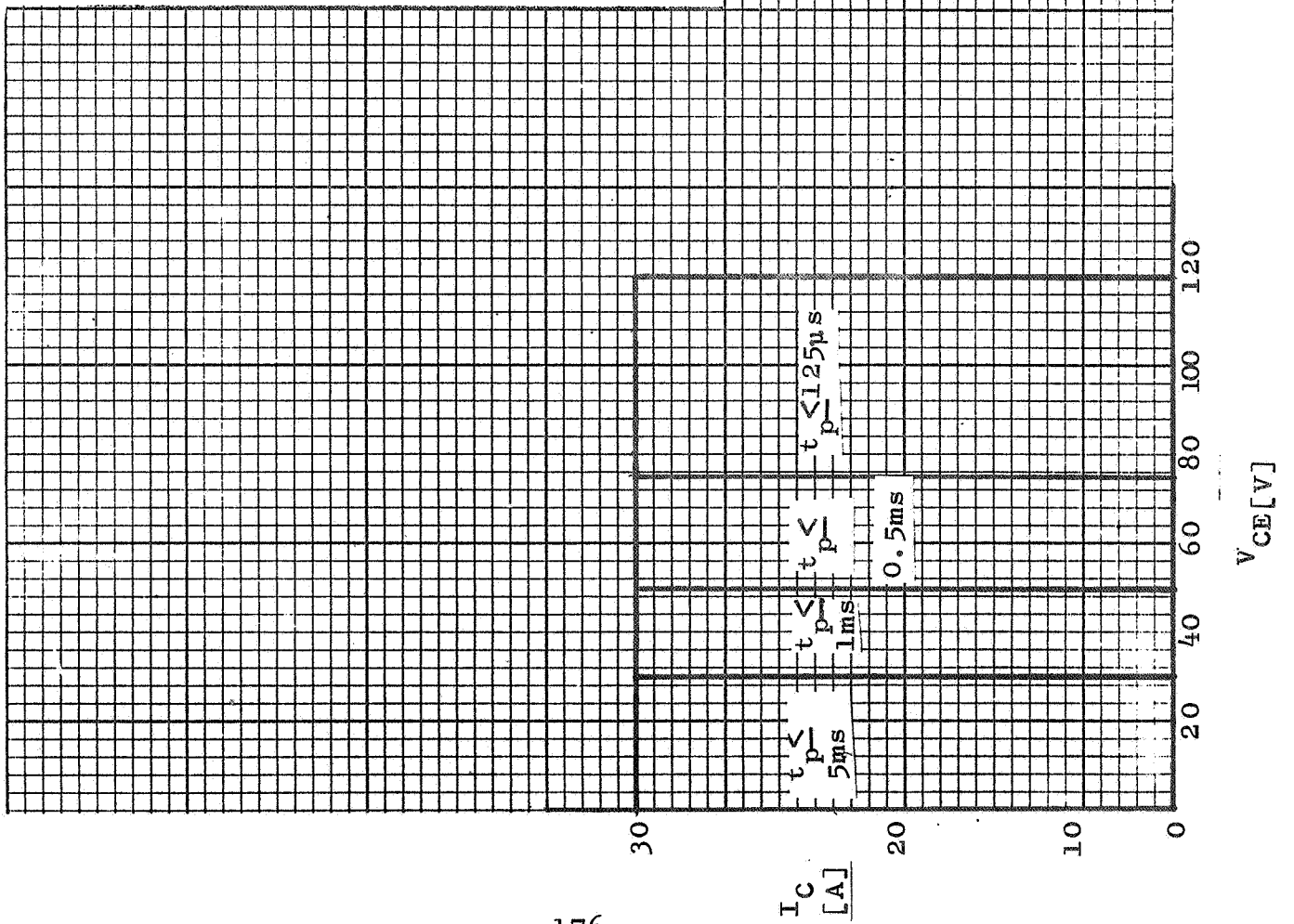


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

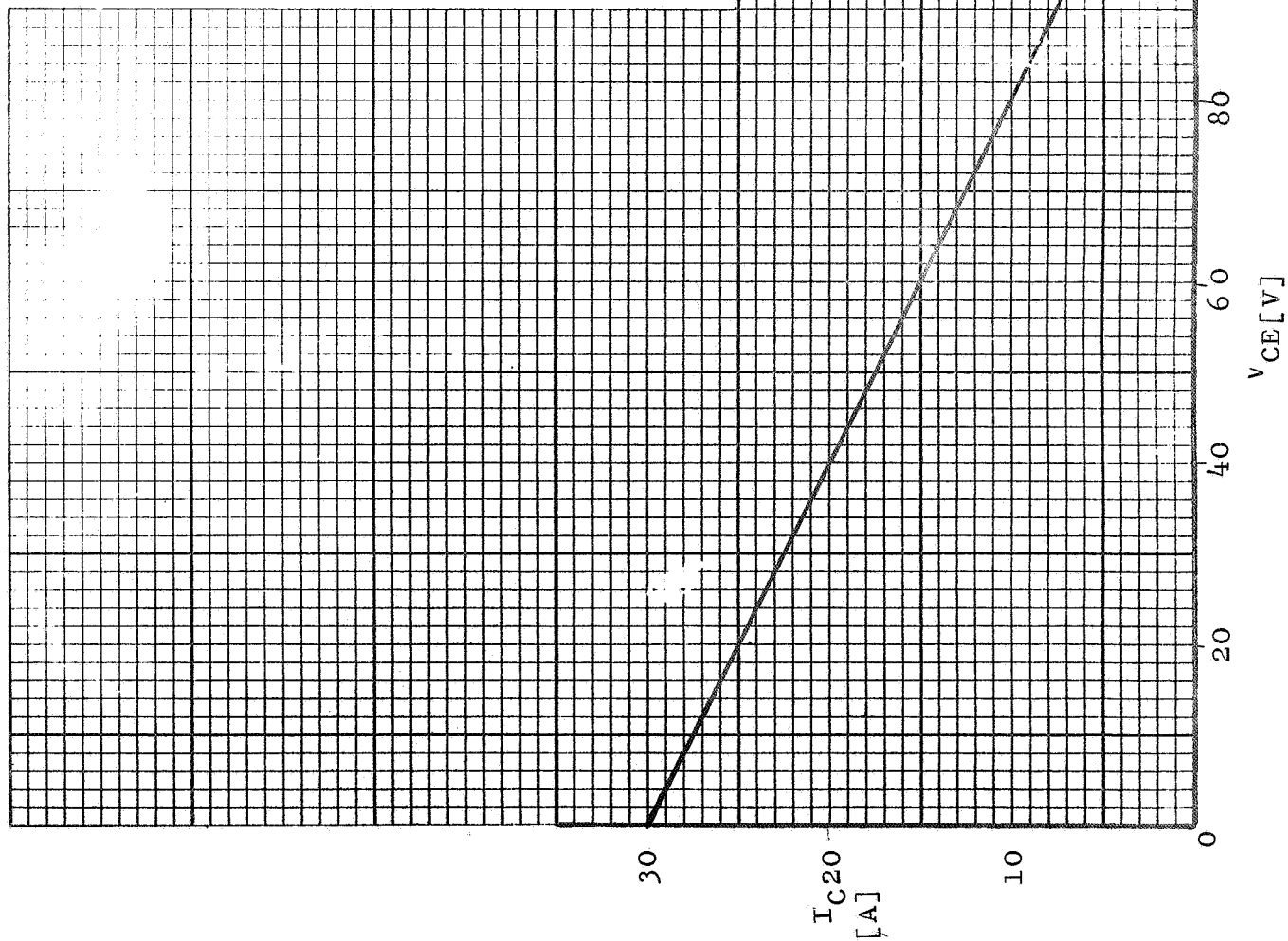
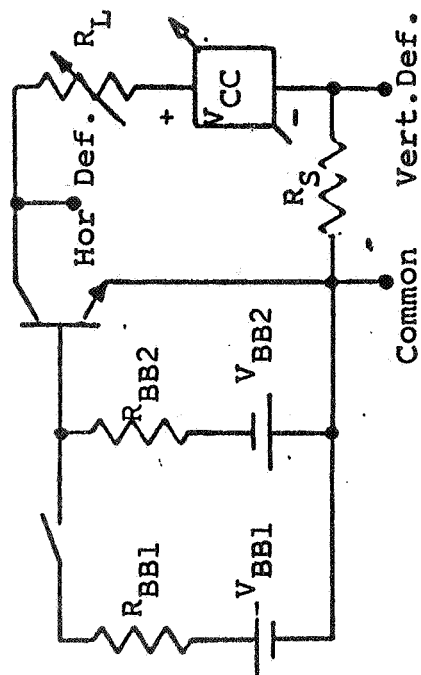
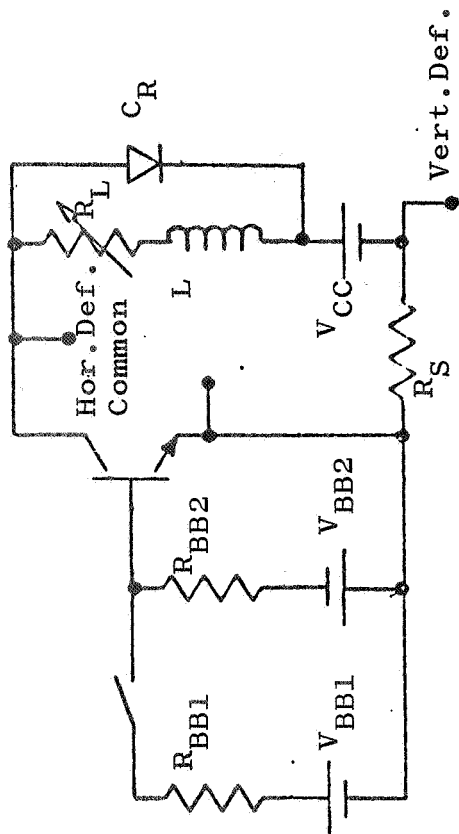
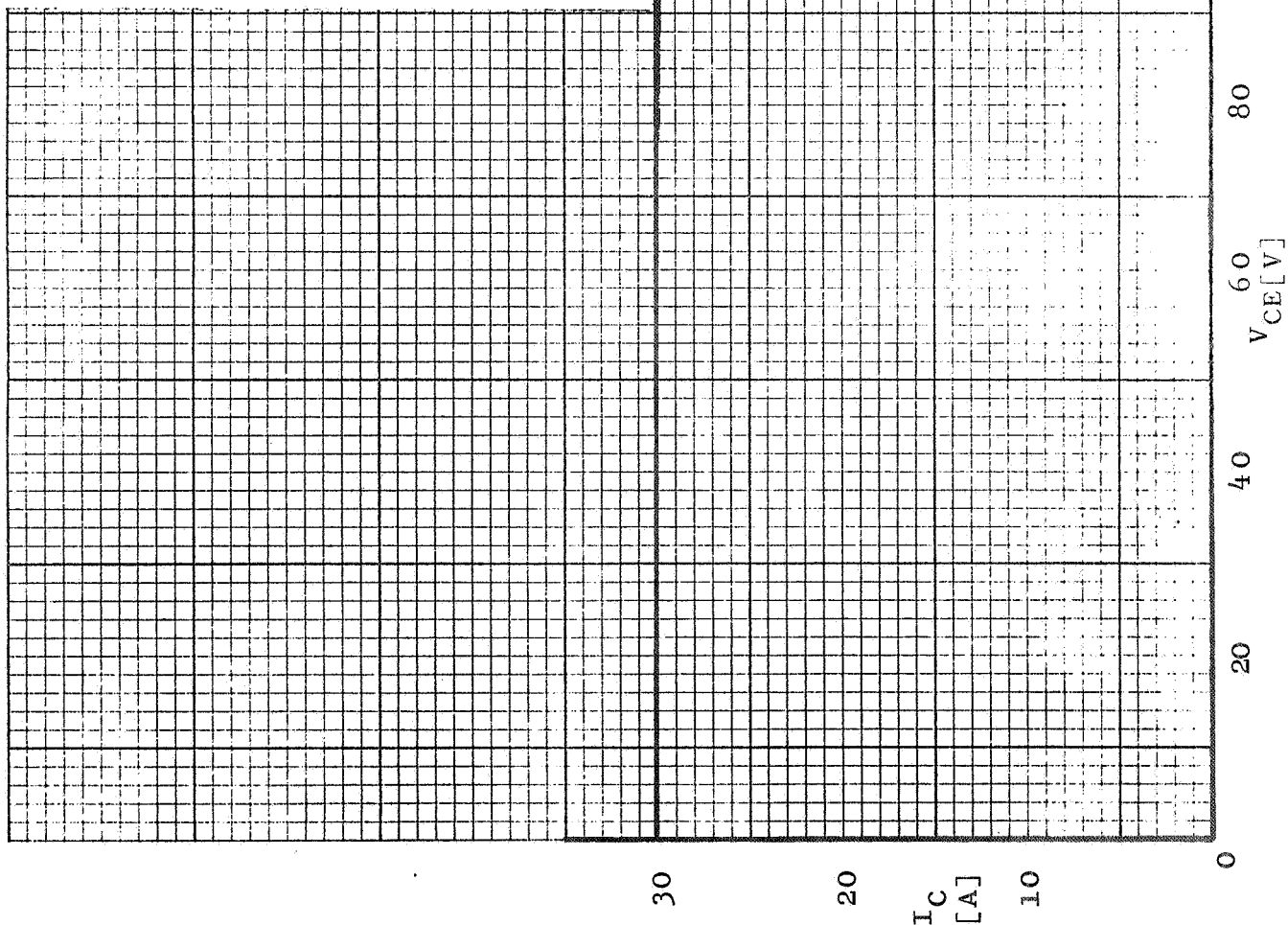


Figure 3



Test Circuit: JS-6-T5.2.1

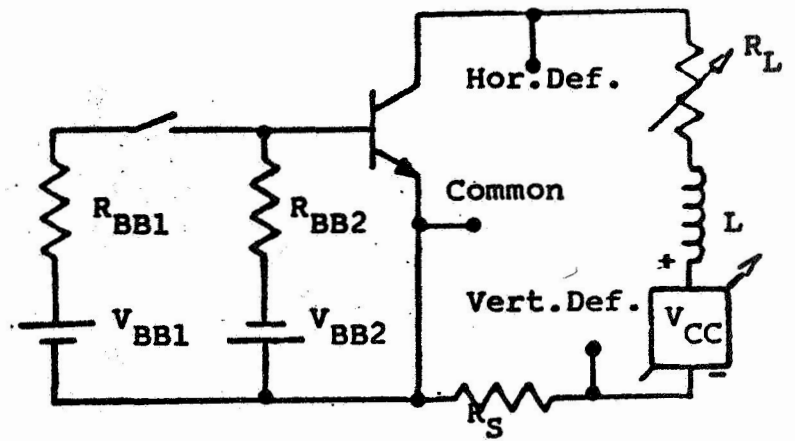
SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

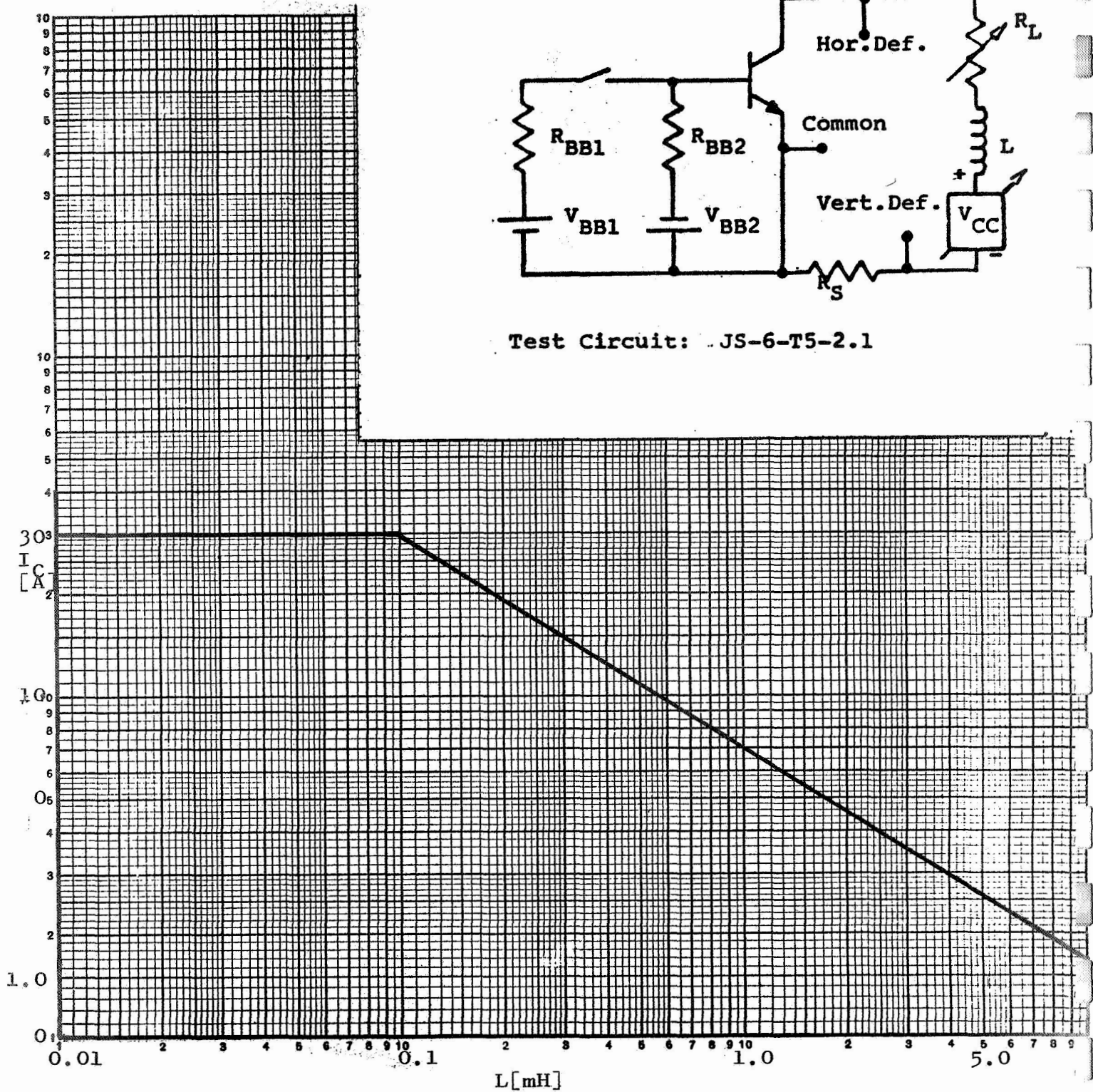
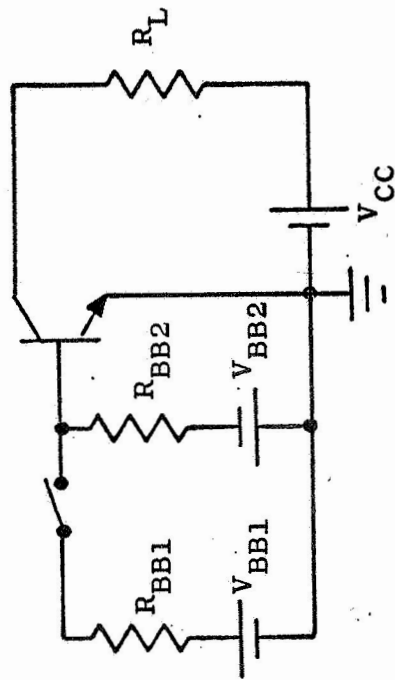


Figure 5

SWITCHING TEST CIRCUIT.



Input Pulse: $t_r < 20\text{ns}$, $t_f < 20\text{ns}$, $t_p = 10\mu\text{s}$
 Duty Cycle = 1%
 $R_{BB1} = 3\Omega$, $V_{BB1} = 11.2\text{V}$
 $R_{BB2} = 4\Omega$, $V_{BB2} = 6\text{V}$
 $R_L = 2\Omega$, $V_{CC} = 31\text{V}$

Figure 6

SHORTED CLASS B SOAR

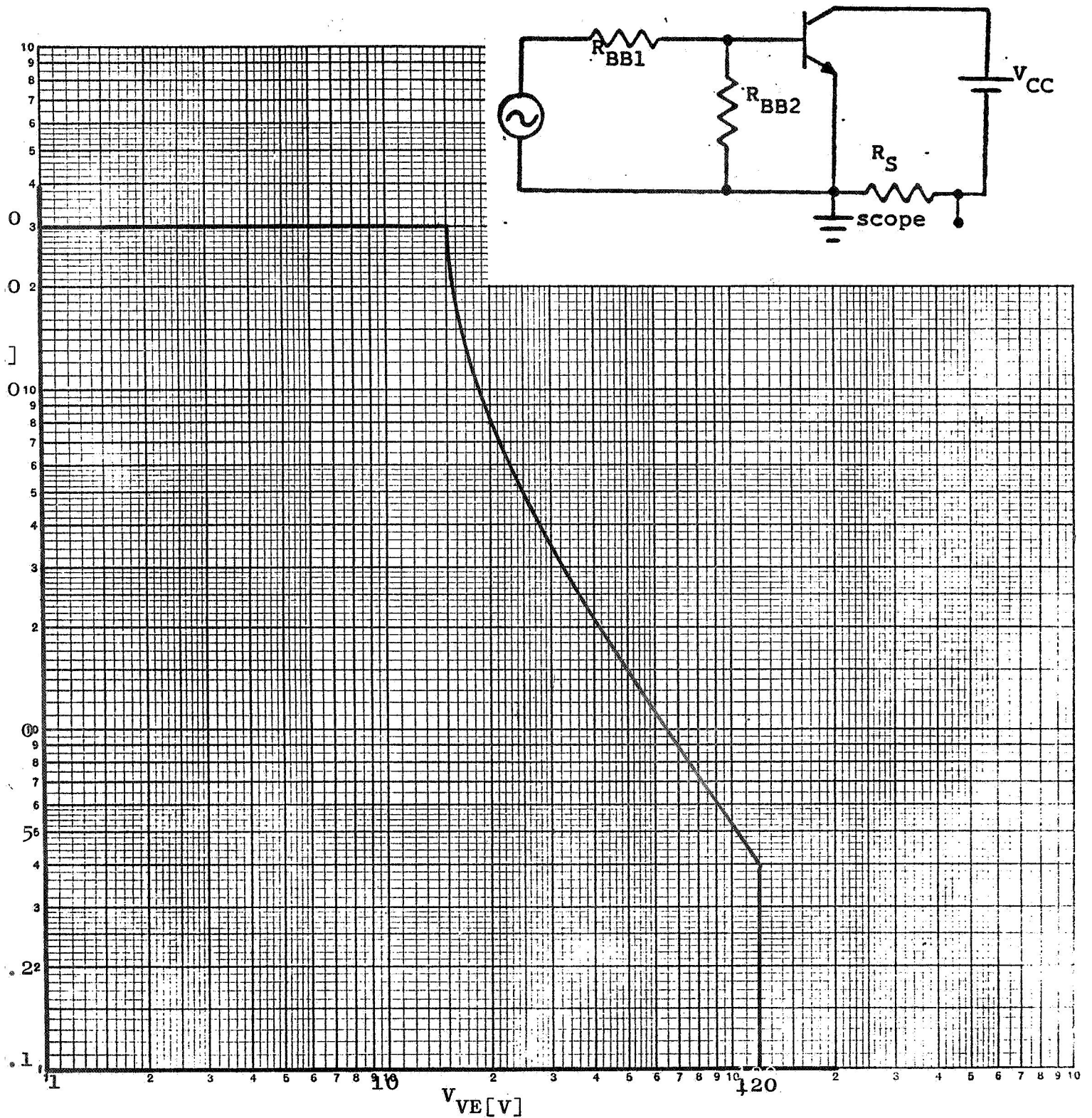


Figure 7

APPENDIX I

ADDENDUM

The reports in Sections 7 and 11 contain the results obtained from two groups of the same type of transistor from two different manufacturers.

This type of testing yielded a better device variation which indicates that wide differences do exist between manufacturers and approved products.

From the data obtained from both groups of devices a single SOAR specification was generated. The combined results expand the JEDEC registration and supplements the specification with complete SOAR curves and test conditions.

Although the test limits encompass both manufacturers devices, some manufacturers may have to re-evaluate their devices at the specified SOAR points.